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Lyons Creek East (Niagara River, Ontario) Area of Concern: benthic conditions in 2015 and temporal trends from 2002 to 2015

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EXECUTIVE SUMMARY

Sediments in Lyons Creek East (LCE) in the Niagara River Area of Concern have been contaminated by polychlorinated biphenyls (PCBs) since at least 1990. Under the Great Lakes Action Plan, Environment and Climate Change Canada (ECCC) assessed benthic conditions in LCE in 2002 and 2003, focusing primarily on the area between the Welland Canal Bypass and Highway 140, where contamination and effects to biota were known to be greatest. In 2008, following a series of additional assessments by other agencies and consultants, monitored natural recovery was selected for the management of the sediments. In support of this plan, ECCC assessed and reported on benthic conditions in LCE in 2010.

In the fall of 2015, ECCC again surveyed LCE to assess current benthic conditions and track recovery. Sampling occurred in LCE and three neighbouring reference creeks (Tee, Beaver and Usshers). Analyses were conducted for sediment chemistry and grain size, PCB bioaccumulation in native invertebrates, benthic invertebrate community structure, and sediment toxicity. Using multivariate and univariate statistical techniques, conditions at LCE sites were compared to those at local (neighbouring) or regional (Great Lakes) reference sites and temporal trends were examined for co-located sites sampled from 2002 to 2015.

A Long Term Monitoring Plan (LTMP) is being developed for the creek by the provincial and federal governments. The bioaccumulation of PCBs in native benthos and surficial sediment contaminant levels were identified as key components to be monitored. Information on benthic community composition and abundance and sediment toxicity were identified as optional supplemental components of the LTMP.

Sediment Contaminants

The surficial (0-10 cm) sediment layer was examined (matching the layer sampled for the LTMP's two supplemental lines of evidence and previous surveys). PCBs are the main contaminants of concern in LCE, but metals, PAHs, and petroleum hydrocarbons were also measured, as they were shown to be elevated in parts of the creek in the past. Contaminant concentrations were compared to sediment quality guidelines and/or to those from neighbouring reference creeks. In 2015, high total PCBs (93 μg/g), total PAHs (63 μg/g), and metals elevated above high guidelines (i.e., Zn, Pb, Ni, As) were observed at a site in the upper creek at Ridge

Road, which could reflect small scale heterogeneity with a hot spot in 2015, as previous surveys indicated much lower concentrations in this area. Elsewhere in LCE, PCB concentrations ranged from 0.03 to 10.5 µg/g compared to ≤ 0.04 µg/g for reference creeks. Total PCB concentrations were above the Probable Effect Level (PEL) between Ridge Road and ~ 3.6 km from the headwaters of the creek (at Cooks Mills). PCBs, expressed in toxic equivalents (TEQ), were below the PEL except at Ridge Road. PCBs have remained stable since 2002, except the site at Ridge Road. Other contaminants (e.g., metals, PAHs, petroleum hydrocarbons) had similar or higher concentrations compared to reference, and were mostly stable or decreasing over time except for the Ridge Road location in 2015.

PCB Bioaccumulation in the Benthos

Native benthic tissue samples, which included amphipods and occasionally chironomids or oligochaetes, were collected at all locations except the site at Ridge Road. Concentrations of total PCBs were compared to those from neighbouring reference creeks, a tissue Reference Concentration (RC), and targets established for the LTMP. PCB concentrations in the benthos remain elevated in LCE, ranging from 207 to 5,140 ng/g, compared to neighbouring reference creeks, where they ranged from 93 to 945 ng/g. Elevated total PCBs in the benthos extended to ~ 3.6 km (Cooks Mills) from the headwaters of the creek, similar to that for the sediments; benthos from the most upstream and downstream had concentrations similar to or below those observed from reference creeks. Tissue PCB levels have remained stable or decreased since 2002 or 2010 with the exception of sites close to or just downstream of Highway 140, where increases were observed in 2015. A long-term target identified for the LTMP is that mean total PCB tissue concentrations in amphipods within zones 1-5 continue to decrease through time such that concentrations are similar to zones farther downstream or to reference sites. The average concentration of total PCBs in amphipods collected in LCE from zones 1 to 5, which included sites from the headwaters up to Cooks Mills, showed no significant change over time, but remain elevated compared to downstream areas and reference creeks by up to ~3.5 times.

Benthic Community Structure

Benthic macroinvertebrate communities in LCE in 2015 were dominated by the oligochaete worm Naididae (249 – 29,554 m^{-2}) and/or the midge Chironomidae (274 – 6,675 m^{-2}) but many other taxon groups were present. Taxa present at 5 or more sites included amphipods (2 families; ≤ 1,448 m^{-2}), mayflies (4 families; ≤ 471 m^{-2}), caddisflies (5 families; ≤ 353 m^{-2}), mites (6 families; ≤ 261 m^{-2}), pisidiid clams (≤ 1,320 m^{-2}), ceratopogonid dipterans (≤ 3,780 m^{-2}), gastropods (5 families; ≤ 422 m^{-2}), and glossiphonid leeches (≤ 60 m^{-2}). The LCE communities were compared to those from the neighbouring uncontaminated reference creeks using ordination and 95% prediction intervals (PIs) computed using the reference creek data. All LCE sites except a site in the upper creek fall within the PIs. This site, located ~ 500 m downstream from the headwaters (LC08), differed due to increased densities of several taxa including amphipods but had lower taxon richness than most other Lyons Creek sites. Individual community descriptors (e.g., total benthos, taxon richness) were mostly similar or lower than reference conditions, whereas others (e.g., evenness and diversity) were more variable. Densities of predominant benthic families found in LCE were mostly similar or lower than those for reference creeks. Over time, benthic communities as a whole appear stable since 2010.

Sediment Toxicity

Sediment toxicity tests were conducted in the laboratory using the freshwater invertebrates *Hyalella azteca*, *Chironomus riparius*, *Hexagenia* spp. and *Tubifex tubifex*. Survival, growth and reproduction were measured for a total of 10 endpoints. In 2015, acute sediment toxicity was restricted to areas upstream of Highway 140. Overall, survival of the amphipod *Hyalella* and mayfly *Hexagenia* were most affected, with toxicity most severe from 80 to 500 m downstream from the headwaters of the creek. Over time, individual endpoint responses (survival, growth, and reproduction) have mostly remained stable. The 2010 and 2015 groups were fairly similar to each other, while the 2002/2003 group was more distinctly different from the successive groups. The shift from 2002 to 2010 and 2015 corresponded to a decrease in *Tubifex* toxicity (increased *Tubifex* cocoon hatching) in 2010 and 2015.

Recovery

The area of LCE from Ridge Road to ~500 m downstream of Highway 140 remains the highest for levels of PCBs in the sediment and benthos; however, elevated concentrations extend to Cooks Mills, approximately 3.6 km from the headwaters of the creek. PCB levels in the benthos and sediments have remained relatively stable since 2002/2003 and the benthic community structure and toxicity has remained stable since 2002 or 2010. The LTMP plan needs to consider the low sediment accumulation rate for Lyons Creek East in order to manage recovery expectations.

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ABBREVIATIONS AND ACRONYMS

ANOVA	analysis of variance
AOC	area of concern
BEC	Beaver Creek
BSAF	biota-sediment accumulation factor
BTEX	benzene, toluene, ethylbenzene and xylene
CABIN	Canadian aquatic biomonitoring network
DL	detection limit
dw	dry weight
ECCC	Environment and Climate Change Canada
GL	Great Lakes
LC	Lyons Creek
LCE	Lyons Creek East
LEL	lowest effect level
LOE	line of evidence
LTMP	long term monitoring plan
max	maximum
min	minimum
MDL	method detection limit
MOECC	Ministry of the Environment and Climate Change
NMS	nonmetric multidimensional scaling
NPCA	Niagara Peninsula Conservation Authority
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEL	probable effect level
PHC	petroleum hydrocarbons
PI	prediction interval
QA/QC	quality assurance/quality control
QEW	Queen Elizabeth Way (highway)
RC	reference concentration
SEL	severe effect level
SQG	sediment quality guideline
TC	Tee Creek
TEL	threshold effect level
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

The Niagara River Area of Concern (AOC) includes tributaries of the Niagara River, one of which is Lyons Creek East (LCE). Originating at the city of Welland, Ontario, LCE runs approximately 17 km from the Welland Canal bypass to the Welland River, which in turn drains into the Niagara River. Contamination of sediment by polychlorinated biphenyls (PCBs) was identified as a potential problem in LCE in the early 1990s (Milani et al. 2013). Since 2002, benthic conditions in LCE have been evaluated periodically as part of Environment and Climate Change Canada's (ECCC) Great Lakes AOC program. A 2002/2003 assessment of general conditions in LCE confirmed PCBs as the primary contaminant of concern due to frequent exceedences of sediment quality guidelines (SQGs) and their biomagnifiable nature (Milani and Grapentine 2006; Milani et al. 2013). The upper 1.5 km reach of the creek, from the headwaters to Highway 140 was previously identified as the most contaminated area and thus the focus for most of the biological work (Milani and Grapentine 2006). In 2008, following a series of additional assessments by other agencies and consultants, monitored natural recovery (with administrative controls) was selected as the best option to manage the contaminated sediments (NPCA 2014). ECCC revisited LCE in 2010 to further evaluate benthic conditions and compare them to those in 2002/2003. The survey of 2015 described in this report was the second since the designation of LCE for monitored natural recovery and coincided with the development of a long term monitoring plan (LTMP). ECCC's contribution to the LTMP includes the assessment of PCB bioaccumulation in native benthic invertebrates with supporting information on surficial sediment chemistry (MOECC and ECCC 2016). Two supplemental lines of evidence (LOEs) - information on the composition and abundance of benthic invertebrate communities and sediment toxicity (evaluated in the laboratory), are optional for the LTMP but were included in the 2015 assessment. Information on the LOE is provided below.

1.2 Assessment Lines of Evidence

Bioaccumulation of PCBs in benthos – to provide evidence of bioavailability from sediments, and assess the potential risk to higher trophic levels due to biomagnification. Invertebrates serve as prey to many fish and can be an important exposure pathway representative of local conditions. A change in biota-sediment accumulation factors (BSAFs) and PCB tissue concentrations over time may reflect a decrease in PCB bioavailability as cleaner suspended material buries PCB contaminated sediment. Amphipod PCB concentrations showed the strongest relationship to sediment PCB concentrations in previous surveys (Milani and Grapentine 2006, 2014) and will be the target organism for collection. Depending on availability, alternate taxa may include chironomids or oligochaetes. The following targets for recovery have been identified for the LTMP (MOECC and ECCC 2016):

a. mean total PCB concentrations in benthos collected from zones 1-4 are to remain the same or decrease relative to concentrations recorded up to 2005, and
b. mean total PCB tissue concentrations within zones 1-5 are to continue to decrease through time such that concentrations are similar to downstream zones or to reference sites.

The zones are depicted in Appendix B, Figure B1, and the sites included in each zone are indicated in Table 1. Zone 1 to 4 is the area from the headwaters to the CN Railway crossing (i.e., LC01 to LC18) and Zone 5 extends to Doan's Ridge Road at Cooks Mills (i.e., LC01 to LC22).

Surficial sediment PCB concentration – to quantify the degree to which sediments are contaminated with PCBs. Additional information on physicochemical attributes of the sediment (e.g., other sediment contaminants, nutrients, particle size) are typically included to assist in the interpretation of biological effects, specifically with respect to the benthic community composition and toxicity (see below). Sampling is from the 0-10-cm depth of sediment, since this layer typically includes the vertical home range of most benthic invertebrates and corresponds to the layer collected for laboratory toxicity testing (see supplemental LOE below). While sediment PCB contamination trends through time can also be examined for the 0-10 cm layer, it would be more appropriate to examine shallower depths to better reflect recent deposits given the low sedimentation rate determined for LCE of 1 mm/year (Golder Associates 2008). The provincial Ministry of the Environment and Climate Change (MOECC) will be examining and reporting on sediment PCB contamination in the 0-3 cm, 3-6 cm and 6-10 cm layer of sediment (taken from core samples) as part of their LTMP contribution.

Benthic invertebrate community structure – to determine whether natural faunal assemblages in LCE differ from those in uncontaminated local reference locations. Trends in commonly used community descriptors such as total benthos, taxon richness, and evenness can also be examined over time. Resident benthic communities in LCE appeared to be different than those in neighbouring reference creeks in 2010 compared to 2002/2003, with declines in family richness, abundance and diversity evident at some sites in the upper reaches of the creek; 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. While this LOE is optional in the monitoring program, due to the results from 2010, it was included in the 2015 survey.

Sediment toxicity – to provide supporting evidence that responses observed in the community are associated with sediment contaminants rather than other potential stressors. Toxicity evaluation (laboratory bioassays with benthic invertebrates) is an optional LOE in LTMP. Previous studies indicated that toxicity was limited to the upper 1 km reach of the creek and that PCBs could only partially explain toxicity based on regression analysis (not a causal relationship). Although, there was similar or reduced toxicity in 2010 at co-located sites compared to 2002/2003, toxicity studies were included in 2015 to verify that conditions are remaining stable.

1.3 Study Objectives

The objective of the 2015 study was to evaluate benthic conditions in LCE and determine whether they are improving over time. The assessments of 2002/2003 and 2010 (Milani and Grapentine 2006, 2014) offered the most recent and extensive data against which changes in benthic conditions through time could be compared, and serve as baseline conditions. Assessments of temporal trends in conditions since 2002 will focus on both the primary LOEs (bioaccumulation with supporting sediment chemistry) and the 2 supplemental LOEs (benthic community structure and toxicity).

Benthic conditions at previously sampled sites were assessed for:

(a) Spatial differences between contaminated and reference sediments in 2015, and

(b) Temporal differences in conditions after 2002 or 2010 for co-located sites.

Reference sites used in the LCE assessments included those from both local and regional locations. Three neighbouring reference creeks, previously chosen by their proximity to LCE and similarities in geomorphological characteristics, were used to compare PCB concentrations in sediment and benthos, and to evaluate the benthic community structure. Regional reference sites were used in the toxicity assessment and represented samples collected from depositional areas of the Great Lakes (GL).

2 METHODS

2.1 Sampling Design

Sampling stations (≡ sites) 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 sites chosen for the LTMP were selected on the basis of (a) results from the 2002/2003 and 2010 studies, (b) representing a range of PCBs levels in sediment in zones 1-5 in LCE, (c) representing least contaminated (e.g., downstream of zone 5) and reference conditions in the area, and (d) overlapping locations of previous studies (co-located sites).

2.2 Sample Collection and Handling

Sampling for the 2015 survey occurred September 14 – 22. Station positions were determined using WAAS enabled hand-held Garmin GPS. All sites sampled in 2002/2003 or 2010 were revisited as closely as possible in 2015. Sample coordinates are provided in Table 1 and locations shown in Figures 1A, B.

Native amphipods for tissue PCB congener analysis were collected with a sweep net at all sites except LC03, which was not sampled due to the unsuitable substrate. Sweeps were carried out close to or among macrophytes (submerged or emerged) for approximately 20 minutes to allow for sufficient biomass to be collected for PCB congener analysis; contents of sweeps were placed in a lined plastic bucket(s) containing site water. Additional taxonomic/functional groups (chironomids, oligochaetes) were collected at 4 sites (LC16, LC18, LC22 and LC38) from the 0-10 cm sediment layer, obtained using a petit Ponar sampler. For these 4 sites, three or four 38-L tubs were filled with sediment to two-thirds full and site overlying water added. From each petite Ponar sample collected, a representative scoop of the 0-10 cm of sediment was placed aside in a glass bowl. Once all sampling aspects were complete (including the benthic community collection described below), sediment in the bowl was homogenized and dispensed to individual containers for the PCB congener and other physico-chemical analyses and stored at -20°C (for organic analytes) or 4°C (for inorganic analytes). Oligochaetes and/or chironomids 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) and sorted in ceramic trays using stainless steel instruments. Due to sample size requirements for PCB congener analysis and time constraints, only one replicate sample per taxon was targeted per site. Sufficient amphipod tissue was collected from all sites except LC03; sufficient oligochaetes were collected from 4 sites (2 LCE and 2 reference), and chironomids from 7 sites (4 LCE and 3 reference). Additionally, duplicate amphipod samples were obtained from 2 sites (1 LCE and 1 reference). Biota were rinsed with reverse osmosis water, placed in pre-weighed and pre-cleaned (20% HCl followed by hexane rinse) 5-mL scintillation vials, weighed and frozen (-20°C). Tissue samples were later freeze-dried and reweighed.

Each site was additionally sampled for site overlying water, benthic invertebrates for community composition analyses, and sediment for laboratory bioassays. Overlying water was collected from just above the sediment surface by bottle (grab) or using a horizontal 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 (TP), nitrates + nitrites-N, total ammonia-N and total Kjeldahl nitrogen (TKN). Benthic invertebrate samples for community structure analysis were collected using five 10-cm length × 6.5-cm diameter acrylic core tubes subsampled from a 40 cm × 40 cm steel mini box core frame inserted into the sediment (6 sites). The remaining 0-10 cm layer of sediment inside the frame was scooped out by hand and set aside in the same glass bowl (described above). If the site was too deep to insert the box core frame into the sediment, samples were collected using a petite Ponar; 3 grabs for benthic community samples and 1 grab (added to the glass bowl), for sediment physico-chemical properties (5 sites). The contents of the tubes or Ponar grabs were sieved through a 250-µm mesh screen and the residue on the screen preserved with 10% buffered formalin for later identification. Samples were transferred to 70% ethanol after a minimum of 72 hours in formalin. Sediment for laboratory bioassays was collected using a petite Ponar grab – 5 replicates per site; sediment from each grab was placed in a plastic bag, cable tied, and stored in buckets at 4°C.

2.3 Sample Analysis

The list of analytes measured in each environmental matrix is provided in Table 2. Analyses of overlying water alkalinity, TP, nitrates + nitrites-N, total ammonia-N and TKN (sum of organic nitrogen and total ammonia nitrogen) were performed by ECCC's National Laboratory for Environmental Testing (NLET) in Burlington, Ontario, using procedures outlined in Environment Canada (2014a). Sediments were freeze-dried and 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 ICP-AES (Inductively Coupled Plasma-Atomic Emission Spectroscopy) (EPA method 6010) or by ICP-MS (Mass Spectrometry) (EPA method 6020) (USEPA 2010a); whole rock (major oxides) by lithium borate fusion followed by ICP-AES (SOP D-ICP-02); total carbon by loss on ignition @ 1000°C; total organic carbon (TOC) by combustion method using a Leco carbon analyzer; total phosphorus by automated colorimetry; and total Kjeldahl nitrogen by semiautomated colorimetry (MOE method 3367). Particle sizes of sediment samples were determined by ECCC's Prairie & Northern Laboratory for Environmental Testing (Edmonton, Alberta). Particle sizing, which included the percents gravel, sand, silt and clay, were determined using sieving apparatus and a Horiba Partica Laser Diffraction Particle Size Analyzer (LA-950). Samples were sieved and then soaked in a hydrogen peroxide solution, dried in an oven overnight, and then soaked in a sodium metaphosphate before entering the Horiba laser analyzer. Sediment and invertebrate tissue samples were analyzed for PCB congeners by ALS Environmental (Burlington, Ontario) by High Resolution Mass Spectrometry (HRMS) using USEPA method 1668C (USEPA 2010b). Sediments were also analyzed for BTEX (benzene, toluene, ethylbenzene, xylene), and the F1 to F4/F4G fractions of petroleum hydrocarbons (PHCs) by ECCC's NLET. BTEX was analyzed by the methanol vortex method, the F1 to F4 PHCs by soxlet extraction silica clean analysis by GC/FIC, and the F4G fraction by extraction (50:50 hexane:acetone) and weighing the residue (gravimetric) based on CCME Canada-Wide standard for PHCs in soil Tier 1 (CCME 2001a). PAHs, analyzed by Maxxam Analytics (Mississauga, Ontario), were extracted by acetone and hexane (1:1) and analyzed by GC/MS; methods were modified from EPA SW846 (3510/8270) (USEPA 2010a).

2.4 Taxonomic Identification

The sorting, identification, verification and enumeration of benthic invertebrate samples were performed by Bohdan Bilyj (Mississauga, Ontario). Laboratory processing of samples followed the Canadian Aquatic Biomonitoring Network (CABIN) protocols (Environment Canada 2014b). Certain taxa and microinvertebrates (e.g., poriferans, nematodes, copepods, and cladocerans) were excluded. Material was sorted under a dissecting microscope (minimum magnification = 10 times), and organisms were enumerated and placed in separate vials by family for identification and verification to lowest practical level.

2.5 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). Sediment handling procedures are described in Milani et al. (2013).

Four sediment toxicity tests were conducted at ECCC's Ecotoxicology laboratory (Burlington, Ontario): *Hyalella azteca* (amphipod) 28-day survival and growth test; *Chironomus riparius* (chironomid) 10-day survival and growth test; *Tubifex tubifex* (oligochaete worm) 28-day reproduction test; and *Hexagenia* spp. (mayfly) 21-day survival and growth test. 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 tests, 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. Tests were carried out as static (i.e., no renewal) exposures 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 total ammonia (ionized and un-ionized) 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*. Feeding was as follows: *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 brewer's yeast once per week, and; *T. tubifex* beakers received 80 mg crushed Nutrafin® fish flakes mixed directly into the sediment prior to the introduction of worms. 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 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. There were 10 test endpoints in total which included percent survival and growth (increase in mg dry weight per individual) for *H. azteca*, C. *riparius* and *Hexagenia* spp. (6 endpoints), and percent survival of adults and reproduction for *T. tubifex* (4 endpoints). Initial weights for *H. azteca* and *C. riparius* were considered negligible. Initial wet weights for *Hexagenia* spp. were predicted to dry weight using a statistical model derived specifically for mayflies, and growth was estimated as the difference between the final and initial dry weights. The three *T. tubifex* reproduction endpoints included the total number of cocoons produced per adult, the percent of cocoons that hatched, and the total number of young produced per adult.

2.6 Data Analysis

2.6.1 Sediment chemistry

2.6.1.1 Contaminant concentrations in 2015

Concentrations of the individual chemical variables measured in the sediments were compared to SQGs: the Canadian Threshold Effect Level (TEL) and Probable Effect Level (PEL) (CCME 1999a), or if there was no TEL/PEL available, to the Provincial Lowest Effect Level (LEL) and Severe Effect Level (SEL) (Fletcher et al. 2008). The low guidelines define the concentrations below which adverse biological effects are expected to occur rarely or which no effect on the majority of the sediment-dwelling organisms is expected. The high guidelines are levels above which adverse biological effects are expected to occur frequently or on the majority of organisms. At concentrations between the low and high guidelines adverse effects may occasionally occur (CCME 1999a). Concentrations of total PCBs were also compared to the 99th percentile for neighboring reference creeks. PCBs concentrations were expressed as total congeners (sum of individual congeners in dw) and as toxic equivalents (TEQs) for the 12 dioxin-like PCBs. The TEQ was calculated using the following equation:

$$\mathrm{TEQ}= \sum_{i=1}^{n} ([\text{dioxin-like PCB}]_i \times \mathrm{TEF}_i)_n$$

Each dioxin-like PCB congener concentration was multiplied by its respective TEF (toxic equivalency factor to 2,3,7,8- TCDD) and all products then summed to give the TEQ value. The World Health Organization (WHO) fish TEFs were used in the calculation (Van den Berg et al. 1998). For values that were below the method detection limit (MDL), the TEQs were calculated by: 1) assigning a value of zero to the non-detected values (lower bound TEQ); 2) assigning the MDL for non-detected values (upper bound TEQ); and 3) assigning half the MDL to non-detected values (mid-point TEQ). Total PAHs for 2015 samples represented the sum of 18 parent compounds: acenaphthylene, acenaphthene, anthracene, benzo[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, benzo[g,h,i]perylene, chrysene, dibenzo[a,h]anthracene, fluorene, fluoranthene, indeno[1,2,3-c,d]pyrene, naphthalene, 1-methylnaphthalene, 2-methylnaphthalene, phenanthrene, and pyrene. PCB and PAH compounds that were not detected were assigned ½ the detection limit for statistical analyses.

To examine patterns in joint organic and metal compounds among 2015 LCE sites, a principal components analysis (PCA) was conducted. Sediment chemistry data included in the

PCA were PCBs as well as PAHs, metals, PHCs, nutrients (TOC, TKN, TP) and particle size (sand, silt and clay). The eigenanalysis was performed on the correlation matrix. PCA was performed using PC-ORD version 6.19 (McCune and Mefford 2011).

2.6.1.2 Trends in contaminant concentrations from 2002 to 2015

Comparisons of sediment concentrations of PCBs (total congeners and toxic equivalents), total PAHs (sum of 16 parent compounds – the above listed compounds minus 1- and 2-methylnaphthalene), total PHCs (sum of F1, F2, F3 and F4G compounds), 8 metals (As, Cd, Cr, Cu, Hg, Ni, Pb, Zn), and 3 nutrients (TOC, TP, TKN) were made by graphical assessments of time series data, showing concentrations from 2002 through to 2015. The range in concentrations for Lake Erie reference sites collected from 2010-2014 (n=19) was also provided for comparison for the inorganic compounds.

2.6.2 PCB bioaccumulation in native benthos

2.6.2.1 Tissue PCB concentrations in 2015

Sites in which concentrations of PCBs in benthic invertebrates were significantly elevated above reference levels were identified by comparing concentrations at LCE sites to the 99th percentile value (~maximum) for the neighbouring reference creek sites. The 12 dioxin-like PCB congener concentrations in invertebrates were expressed in toxic equivalents (TEQs) as described for sediments (Section 2.6.1) but using the WHO avian TEFs (Van den Berg et al. 1998). The PCB TEQs for LCE were compared to an avian Reference Concentration (RC) of 5.5 pg TEQ/g ww. This RC was derived using the highest food ingestion to body weight ratio (FI: bw) of an anseriforme (female bufflehead; 0.42) (CCME 1999b). The avian RC for PCBs of 2.4 pg TEQ/g ww (CCME 2001b) was not used as this value is based on the FI: bw of Wilson's storm-petrel, a seabird not found in LCE. An avian RC was used since an avian receptor (e.g., diving duck) would feed directly on benthic invertebrates. The adopted TRGs for PCBs (0.79 pg TEQ/g diet ww), while lower, was not used since it was derived from studies on mammalian receptors (mink).

Relationships between concentrations of total PCBs in sediment ($[PCB]_{sed}$) and amphipods ($[PCB]_{amp}$), normalized to % TOC and lipids, respectively, were examined using simple linear regression (ordinary least squares) for a single predictor ($[PCB]_{sed}$) model.

Regression analysis was performed using SigmaPlot version 12.5 (Systat Software, Inc., San Jose California USA, www.sigmaplot.com).

The bioavailability of the dioxin-like PCBs was quantified through the calculation of biota-sediment accumulation factors (BSAFs). The BSAF was defined as:

$$BSAF = (C_o/f_l) / (C_s/f_{toc})$$

where C_o = the congener concentration in the organism, f_l is the lipid fraction in the organism, C_s is congener concentration in the sediment, and f_{toc} is the fraction of total organic carbon in the sediment. The BSAFs assume that the concentration of contaminant in the organism is a linear function of the contaminant concentration in the sediment. The BSAFs were calculated with co-detected tissue and sediment congeners for the 2015 samples. Lipid values used in the calculations of BSAFs were obtained from where native invertebrate tissue collected from LCE in 2003 (Milani and Grapentine 2006); the average % lipid values used were 5.74%, 8.59%, and 15.86% for amphipods, chironomids, and oligochaetes, respectively.

2.6.2.2 Trends in tissue PCB concentrations from 2002 to 2015

Trends in invertebrate tissue PCB concentrations, expressed as total congeners and TEQs, were examined for three sampling periods. Comparisons were made by graphical assessments of time series data, showing amphipod tissue concentrations in 2002/2003, 2010, and 2015 from co-located sites. Trends in the average total PCB concentration in amphipods collected from zones 1 to 5 were also examined from 2002 to 2015 (n=3-6 sampling points for each year) and a one-way analysis of variance (ANOVA) at α=0.05 was performed to test for differences in PCB concentrations between years. Data were log(x)-transformed to meet assumptions of normality. The ANOVA was performed using SigmaPlot version 12.5 (Systat Software, Inc., San Jose California USA, www.sigmaplot.com).

2.6.3 Benthic invertebrate community structure

2.6.3.1 Benthic community structure in 2015

The approach taken for this assessment was to determine conditions in LCE in 2015 based on benthic composition and how they differed from the neighbouring reference creeks. The reference creeks were deemed appropriate for comparison to LCE based on five parameters: watershed area, stream order, wetland percentage, flow type, sediment type and contamination

(Milani et al. 2013). To summarize the predominant pattern in the benthic community data, log (x+1)-transformed macroinvertebrate family counts from the LCE and neighbouring reference creek sites sampled in 2015 were ordinated by nonmetric multidimensional scaling (NMS) applied to a Bray-Curtis distance matrix. Row data were modified by general relativization prior to analysis. The best solution for the NMS was selected as the one with the lowest number of dimensions whose final stress differed by < 5 (out of 100) from that of the next higher dimension solution. The dimensionality of the best solution was considered significant if its final stress was lower than 95% of Monte Carlos randomization runs (McCune and Mefford, 2011). A total of 26 families were used in the analysis; families with 1 or 2 occurrences were removed from the dataset. For each invertebrate family, the correlation coefficient was calculated with each ordination axis; these coefficients express the linear (Pearson's r) and rank (Kendall's tau) relationships between the ordination scores and the individual variables used to construct the ordination (McCune and Mefford 2011). Similarly, the relationship between a set of environmental variables and ordination scores was also examined (correlation coefficients calculated). Environmental variables were log-transformed or arcsine squareroot transformed (for percentages) prior to analysis and included sediment metals, organic contaminants, nutrients, particle size and overlying water nutrients, alkalinity, pH and dissolved oxygen (most variables that are listed in Table 2). NMS was performed using PC-ORD version 6.19 (McCune and Mefford 2011).

The LCE site scores in NMS space were also compared to prediction intervals (PIs) computed using the 2015 neighbouring reference creek benthic community data. The 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).

2.6.3.2 Trends in benthic community structure from 2002 to 2015

To examine how the responses in the sample units (sites) varied over time, NMS applied to a Bray-Curtis distance matrix was performed for the co-located sites sampled in 2002/2003, 2010 and 2015 (LCE data only). Families with 1 or 2 occurrences were removed resulting in a total of 37 families used in the assessment. The number of families was not the same as above (A. 2015 conditions) since the time series analysis involved 3 separate datasets combined (2002/2003, 2010, 2015). Benthic data were log (× + 1)-transformed prior to analysis and dimensionality was determined as described above. Invertebrate families were again correlated with each axis as was a set of environmental variables that was consistent to all three sampling periods (which resulted in PHCs being excluded). To visually assess the change over time as a whole, an outline (polygon) of the ordination space defined by the three groups (years 2002, 2010 and 2015) was added that connected the outermost points. To gauge differences between the groups of sampling units, multi-response permutation procedure (MRPP) was employed using the Bray-Curtis distance measure. MRPP is a nonparametric multivariate test of differences between groups that provides a p-value and a measure of effect size known as the 'within-group agreement' value ('A'); as the similarity of sample units within groups increases, A increases (Peck 2010). To explore which invertebrate families were responsible for observed differences among the groups based on their constancy and distribution of abundance, Indicator Species Analysis (ISA) was conducted. Indicator values (IVs) were calculated using the method of Dufrêne and Legendre (1997). MRPP and ISA were performed using PC-ORD version 6.19 (McCune and Mefford 2011). Community descriptors were also plotted in time series to show comparative temporal variation from 2002 to 2015. Benthic community descriptors included total benthos, family richness, Pielou's evenness, Shannon's diversity index, and the densities of five dominant taxon groups: naidid (oligochaete) worms, chironomids, amphipods, mayflies and caddisflies.

2.6.4 Sediment toxicity

2.6.4.1 Toxicity in 2015

Data analyses to assess sediment toxicity were made by comparisons of LCE and neighbouring reference creek sites to 66 GL reference sites using NMS applied to a relative Euclidean distance site × site distance matrix. NMS was first run using the GL reference data only. Dimensionality was determined by the stress value as described in Section 2.6.3. LCE and local reference creek data were then fitted into the ordination space constructed with the GL reference sites and for each site (one at a time), the best fit (lowest stress) position was determined on each of the existing axes. Stress was calculated, and once the lowest stress position was determined, it became the ordination score for the site. To evaluate how the toxicological responses influenced the resulting pattern, correlation coefficients were calculated for each endpoint with the ordination axes. The LCE and local reference site scores were then assessed by graphical comparison to confidence bands for the 66 GL reference site scores (Reynoldson et al. 2000, 2002). Three probability ellipses, 90%, 99%, and 99.9%, were constructed around the 66 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
Band 4 - outside the 99.9% ellipse	= severely toxic

NMS was performed using PC-ORD version 6.19 (McCune and Mefford 2011) and probability ellipses constructed using Systat 12 (Systat Software, Inc., San Jose California USA, www.systatsoftware.com).

2.6.4.2 Trends in toxicity from 2002 to 2015

To examine how the responses in the sample units (sites) varied over time for LCE, NMS applied to a Euclidean distance matrix was performed for co-located sites sampled in 2002/2003, 2010 and 2015. Column (endpoint) data were relativized by maximum prior to analysis. Dimensionality was determined as described in Section 2.6.3. For each endpoint and set of environmental variables, correlation coefficients were calculated with each axis, as described in Section 2.6.3. The environmental variables (log or arcsine square root-transformed for percentages) included those that were consistent to all three sampling years used and included the sediment variables listed in Table 2 with the exception of PHCs. To visualize how changes in response occurred as a whole over time, outlines (polygons) of the ordination space defined by the three groups (years 2002, 2010, and 2015) were added. To gauge differences between the groups of sampling units, MRPP was employed using the Euclidean distance measure (see Section 2.6.3 for description of MRPP).

The 10 individual toxicity endpoints were also plotted in time series graphs to examine variation over time. The key feature of the representations is the change through time in how the LCE and reference creek sites compared to the mean and variation (2 standard deviations (SD)) from the mean for the GL reference sites.

2.7 Quality Assurance/Quality Control

In the 2015 sampling survey, a minimum of 1 in every 10 sites was randomly selected as a QA/QC site, where triplicate samples of overlying water, sediment chemistry and benthic invertebrate community were collected for determination of within-site and among-sample variability. One site was designated for QA/QC: LC12. Three unique field replicate samples were collected at this site during the sampling phase of the program and treated as separate samples throughout the rest of the sample preparation and analysis phases. The variation among the field-replicated analytical data was examined using the coefficient of variation (CV) which is the ratio between the standard deviation (SD) and the mean multiplied by 100.

Laboratory analysis

Quality control procedures for the analytical work included the analysis of method blanks, matrix spikes, surrogate spikes, certified reference material (CRM), laboratory control samples (LCS) and sample duplicates, which were used in each analytical run (generally every 1 in 10 or 20 samples). The precision of sample duplicates was evaluated using the relative percent difference (RPD), defined as $RPD = (x_1 - x_2)/((x_1 + x_2)/2) \times 100$. An acceptable range of values for the quality control results was provided for each analyte by the laboratory conducting the analysis.

Invertebrate sorting and taxonomy

For the benthic invertebrate identification and enumeration, 10% of samples were re-sorted and checked by a different sorter from the original. 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 QA 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 and identification errors (IEs) recorded. If the IE was > 5%, then corrective measures were implemented according to CABIN protocols (Environment Canada 2014b). Data entry QA involved visual confirmations of the taxonomic identification and number of specimens in each taxon. Benthic data were bulk uploaded on the CABIN database from an excel file.

Laboratory bioassays

Bias was assessed through the use of control sediment, which contained only background quantities of the analytes of interest. This control sediment was collected from Long Point Marsh, Lake Erie (42°35.213′ N, 80°27.130′ W) and was run concurrently in each test set. The test organism's response to the control sediment was used to establish test validity; data that was within the bias window, e.g., mean plus or minus 2 SDs and percent survival greater than a set limit established for this sediment, were carried forward in data analysis. Warning charts were constructed for each of the chronic responses using a minimum of seven points. Tests that did not pass set criteria were repeated until they passed.

3 RESULTS AND DISCUSSION

3.1 Quality Assurance/Quality Control

Among-site variability 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-site variability indicates the overall error associated with conditions at a site based on a single sample. In 2015, 3 unique field replicate samples were collected during the sampling phase of the program at site LC12 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. Variability in field-replicated sediment sample measurements, expressed as the coefficient of variation (CV), is provided in Appendix A, Tables A1-A4. Where analytes were not detected in the sediments, the CVs were not calculable. For trace metals, metal oxides and nutrients, variability was low with CVs ranging from 0 to 43.3 % (mean 7.6%); most samples (91%) had CVs < 20%, very good for field-replicated samples (Appendix A, Table A1). Variability was overall higher for the organic contaminants. For PHCs (BTEX and F1 to F4G) CVs ranged from 31.4-66.4% (Appendix A, Table A2), for PAHs and total PCBs ranged from 5.3 to 74.1% (mean: 37.6%) (Appendix A, Table A3) and for PCB congeners, ranged from 10.6 to 103.6% (mean 56.3%) (Appendix A, Table A4). Typically higher variation occurs when analytes are present in low concentrations and significant variability can 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 showed 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). While there were differences in variability among the various parameters, overall results indicated relatively consistent results between box cores taken from the same site and low within-site variability.

Laboratory sample duplicates

Analytical precision was measured by analyzing subsamples in duplicate (intralaboratory split samples). For trace metals, metal oxides and nutrients, a relative percent difference (RPD) < 20% indicated that the measurements were within precision standards. Sample duplicates showed good agreement, with the RPD for metals and nutrients ranging from 0 to 23.0% (mean: 4.7%) (Appendix A, Table A5). The RPDs for PAH and total PCB sample duplicates were not calculable due to non-detect values (Appendix A, Table A6). For PCB congeners, RPDs were low, ranging from 0.5 to 30.1% (mean 13.4%) for individual congeners, indicating very good precision (Appendix A, Table A7); RPDs for homologue groups were higher, ranging from 6.8 to 75.9% (mean 23.5%) (Appendix A, Table A8).

Reference material/standards

Reference material/standards are analyzed to assess the bias of measurements being made at the analytical laboratory. Commonly used reference materials (RMs) 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 metal and nutrient analyses, four RMs were processed and analyzed with each batch of samples; recoveries were ≥ 79%

(mean: 98%) and all values were within the confidence limits (CLs) specified for each parameter (Appendix A, Table A9).

Laboratory control samples

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. Percent recoveries of target analytes in the LCS are compared to established control limits and indicate whether the laboratory was capable of making accurate and precise measurements at the required reporting limit. The recoveries of PCB congeners in LCS run concurrently with sediment and tissue samples are provided in Appendix A, Tables A10 and A11, respectively. No samples were flagged. For sediment samples, recoveries ranged from 88-120% (mean: 104.6%) and for tissue samples they ranged from 94-128% (mean: 109.8%), indicating good accuracy was obtained by the laboratory for these analytes.

Matrix/blank spikes

A matrix spike consists of the original sample matrix to which a known amount of a compound similar chemically to the target analyte or a surrogate (see below) is added and is used to evaluate sample matrix interference. A blank spike (also called a LCS) is also spiked with a known amount of compound but is an interference free matrix and is used to evaluate method accuracy. Recoveries of PAHs, total PCBs, in spiked matrix and blanks spikes are provided in Appendix A, Table A12. Recoveries ranged from 72 to 89% (mean: 81%) for matrix spikes and from 71 to 96% (mean: 84%) for blank spikes; all recoveries were within the established control limits. For F1 to F4/F4G fractions of PHCs, good recoveries were obtained in spiked blanks which ranged from 99-102% and for BTEX recoveries in LCS/spiked blanks and duplicates ranged from 97.5 to 108%; the RPD for spiked duplicates ≤ 8.59% indicating good precision as well (Appendix A, Table A13).

Surrogates

A surrogate is a pure or isotopically labeled organic compound whose behavior mirrors the analytes of interest and is used to evaluate extraction efficiency. Acceptable surrogate spike recoveries are set at 100 +/- 30 percent (USEPA 1994). Surrogates are spiked into routine samples or blanks, standards, and LCS prior to extraction and are 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. Surrogates in the current study included D10-Anthracene, D14-Terphenyl, D8-Acenaphthylene for PAHs and decachlorobiphenyl for PCBs. Recoveries of surrogates ranged from 74 to 95% (mean: 85%) in spiked matrix and from 76 to 102% (mean: 89%) in spiked blank (Appendix A, Table A14). Recoveries of surrogates spiked into the routine LCE samples ranged from 56 to 105% (mean: 88.5%) for PAH surrogates and from 77 to 108% (mean: 88.9%) for the PCB surrogate (Appendix A, Table A15); values were within the established control limits.

Method blanks

A method blank (MB) is an analyte-free matrix that was subjected to the same preparation and analytical procedure as the regular samples and is used to document contamination resulting from the analytical process. It provides confidence that the values reported in the samples are "real" and not the result of laboratory contamination. The MBs were included with the analysis of every organic contaminant sample preparation batch and results should generally be below the reporting limit or MDL for most analytes being tested or within 5% of the measured concentration in the sample. Results for MBs are provided in Appendix A, Table A13 and Tables A16-A18. The MB for the FI fraction of PHCs was 7.89 µg/g, ≤ 1.63 µg/g for the F2-F4 fractions and non-detect for F4G (Appendix A, Table A13). These values were mostly 2-3 times < the lowest measured concentration in the test samples, indicating there was confidence in the values for the test samples. While the MB for the F1 fraction was higher, F1 concentrations in the actual samples were below MDLs (Table 7). PAHs, total PCBs and most PCB congeners were not detected in the MBs run with sediment samples (Appendix A, Tables A16-17). Detecting PCB congeners in MBs is almost unavoidable (the highest was 5.76 pg/g). Typically, for 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.). The MBs run with tissue samples were typically higher (Appendix A, Table A18); however, MB concentrations were several fold lower than the lowest concentrations in the test samples (reference creek samples), indicating there was confidence in the values for the test samples.

Invertebrate sorting and taxonomy

A total of 48 samples were sorted for the 2015 LCE study following procedures outlined in the CABIN protocol. Five samples (10%) were audited for sorting efficiency (SE) and taxonomic identification errors. The SEs ranged from 82.1 to 100% with an overall average of 95.7% (Appendix A, Table A19). The average SE was above the acceptable level (≥ 95%) indicating that a good representation of the benthic community was achieved and that no resorting of the samples was necessary.

The taxonomic identification errors (IEs) for each set of samples are reported in Appendix A, Table A20. There were no misidentifications in the 5 QA/QC samples (IEs = 0%). This met CABIN's quality objectives of < 5% and therefore no corrective actions were required. Counts differed slightly in some samples which were likely lost in transfer. The chironomid *Polypedilum simulans* was changed to *Polypedilum halterale* grp, to take a more conservative position and was applied to all other samples (Appendix A, Table A20). *P. simulans* and *P. halterale* are very difficult to separate as larvae and there is nothing in the taxonomic literature to separate the larvae of all the species within the *Polypedilum halterale* grp which consists of 5 species including *P. simulans* (B. Bilyj, pers. comm).

Laboratory bioassays

Bioassays had to pass set criteria or data quality objectives before the data were used in analyses. Six sets of bioassays were conducted for each test organism with 1-3 sites per set. All original tests passed criteria based on toxicological response (survival, growth and reproduction) in the laboratory control sediment run concurrently with the LCE sediment (Appendix A, Table A21).

3.2 Sediment Polychlorinated Biphenyls

3.2.1 PCB concentrations in 2015

Concentrations of total PCB congeners in LCE sediments (0-10 cm) ranged from 33 to 93,200 ng/g dw in 2015 (Table 3). Concentrations at 7 of the 8 LCE sites were elevated compared to neighbouring reference creeks, where they ranged from 2.1 to 42.2 ng/g (Table 3). The reported average concentration for the eastern basin of Lake Erie is 36 ng/g (Marvin et al. 2004). The tetra-chlorinated biphenyl homologue group dominated the LCE samples (36-53% of total homologue group totals) and of the dioxin-like PCBs, PCBs-118 and -105 were dominant with median concentrations of 61,200 and 33,050 pg/g, respectively, followed by PCB-77 (median 11,250 pg/g). All LCE sites except LC38, located farthest downstream, exceeded the PCBs 99th percentile (= maximum) for reference creeks by 1 to 3 orders of magnitude while the freshwater Probable Effect Level (PEL) for total PCBs (0.277 µg/g) was exceeded at 6 of the 8 LCE sites - from LC03 to LC22 (Figure 2). Site LC03 (Ridge Road) had unusually high PCB concentrations in 2015 (total PCBs: 93,200 ng/g; Table 3) compared to that found in previous years (≤ 17,300 ng/g) (Milani et al. 2013; Milani and Grapentine 2014). This could reflect small scale heterogeneity as there were differences in sample location between years (the 2015 location was 8.5 m from the 2010 location) with the 2015 location representing a hot spot within the area of site LC03 that was previously undetected. A smaller second peak in PCBs occurred at LC12 (10,487 ng/g; Table 3) after which concentrations decreased with distance downstream (Figure 2). Under the mid-point scenario (non-detects were assigned ½ the MDL), the dioxin-like PCB TEQs ranged from 0.08 to 78.3 pg TEQ/g for LCE sites compared to ≤ 0.103 pg TEQ/g for neighbouring reference sites (Table 3). The TEQs were compared to the polychlorinated dibenzo-*p*-dioxins/dibenzo furans PEL of 21.5 ng TEQ/kg (CCME 1999a); exceedance of the PEL occurred only at LC03 in 2015 (Table 3) which differed from 2010 where exceedences extended from LC03 to LC18, and from 2002/2003, where only one site (LC19) just slightly exceeded (Milani and Grapentine 2014).

3.2.2 Temporal change in sediment PCB concentrations: 2002 to 2015

Trends in sediment total PCBs congeners and TEQs from 2002 to 2015 for co-located sites are shown in Figures 3A and 3B, respectively. Total PCB concentrations have remained relatively stable since 2002, with increases observed in 2010 followed by decreases in 2015, with the exception of site LC03, where the unusually high concentration was found in 2015 (Figure 3A). (Potential reasons why concentrations were high at LC03 are provided above in Section 3.2.1.) In 2002/2003, PCB concentration peaked at ~ 80 m from the source or headwaters of LCE at LC03 (12,548 ng/g) whereas in 2010 it peaked at ~1000 m at LC12 (36,100 ng/g). With the exception of LC03, concentrations in 2015 more closely resembled those form 2002/2003 (Figure 3A). Similar trends were observed for PCBs expressed as TEQs (Figure 3B). While trends in the 0-10 cm sediment were included here, the LTMP for LCE has identified short term and long term PCB targets for the surficial 0-3 cm sediment. This was deemed more appropriate due to the low sedimentation rate of 1 mm/year determined by Golder Associates (2008). Sediment data from the 2015 study provided supplemental information for the assessment of other LOE (e.g., community structure, toxicity), but could also be compared to the MOECC data (0-3 cm, 3-6 cm and 6-10 cm layer of sediment).

3.3 Additional Sediment Characteristics

To assess the dominant linear patterns for the 2015 sediment data, a PCA was performed using information on PCBs (total congeners and TEQs) as well as PAHs (sum of 18 parent compounds), total PHCs, metals (Al, As, Cr, Cu, Fe, Pb, Hg, Mg, Mn, Ni, Zn), nutrients (total P, TKN, and TOC), and particle size (percents sand, silt and clay). Site scores and variable loadings for the first 2 components, which accounted for 82.3% of the variation in the data, are shown in Figure 4A. The first principal component summarized the redundancy among metals (except Al, Mn, and Mg), organic contaminants and total phosphorus, while the second principal component summarized the redundancy in particle size and Al (Figure 4A). The third principal component (not shown), which accounted for 9% of variation, summarized the redundancy in Mg, Mn, TOC and TKN. There was a distinct separation of LC03 from remaining sites along the first axis influenced by metal and organic contaminants, most of which had similar loadings for PCA Axis 1 (Figure 4A). The reference creek sites (UC01 and BEC02) had higher proportions of sand particles while remaining sites were characterized by increased concentrations of nutrients and/or silt/clay particles (Figure 4A). A PCA was also performed without site LC03 because of its unusually high PCB (and other contaminants) concentrations. This resulted in a clearer separation among remaining sites on both axes, which accounted for 79.3% of the variation in the data (Figure 4B). The first principal component summarized the redundancy among 6 of the metals plus TKN, TP and sand and clay while the second principal component summarized the redundancy in organic contaminants, Mn, and silt (Figure 4B). Sites LC08 to LC16 were influenced by increasing contaminant concentrations. Additional sediment elements are discussed individually in more depth below.

3.3.1 Polycyclic aromatic hydrocarbons

In 2015, PAHs (sum of 18 parent compounds) ranged from 0.9 to 63.8 µg/g in LCE sediments (Table 4). Similar to PCBs, the highest PAH concentration occurred at LC03 after which there was a decline followed by a smaller peak at LC12 (3.83 µg/g); concentrations decreased with distance downstream from LC12 (Figure 5). Total PAHs exceeded the LEL (4 µg/g) and the 99th percentile concentrations for neighbouring reference sites (6.87 µg/g) at LC03 (Figure 5) but all LCE sites (as well as reference sites) had individual PAHs exceeding LELs (Table 4). Exceedences of the PEL for individual PAHs occurred only at LC03, where pyrene and fluoranthene were dominant; however, there were 1-4 PEL exceedences for reference sites as well (Table 4). Other than LC03, PAH concentrations in LCE were within the range observed for reference sites (0.6 to 6.95 µg/g) (Table 4).

Trends in concentrations of PAHs (sum 16 parent compounds) from 2002 to 2015 are provided in Figure 6A. PAHs have remained generally stable since 2002 with the exception of LC03 (same that was found for PCBs). Increased concentrations observed in 2010 at sites LC12 and LC18 were followed by reverses in 2015 (Figure 6A), similar to PCB trends (Figure 3).

3.3.2 BTEX and petroleum hydrocarbons

The volatile organic compounds, BTEX, which are six compounds - benzene, toluene, ethylbenzene, and meta, para and ortho-xylene, are mostly associated with gasoline (CCME 2001a). These compounds, as well as the F1 fraction of PHCs were either below MDLs or present in low quantities in 2015 (Table 5). Toluene was detected throughout LCE (0.32-2.56 mg/kg) as well as in the reference creeks (≤ 1.1 mg/kg) and xylenes were detected at LC03 and LC12 (≤ 0.97 mg/kg) (Table 5). Total PHCs (sum of F1, F2, F3 and F4G) ranged from 1,157 to 58,416 mg/kg and were overall highest at site LC03, with concentrations decreasing with distance downstream of LC03; neighbouring reference creek concentrations were ≤ 1,662 mg/kg (Table 5). The F4G fraction (heavy ~C24-C50+ hydrocarbons), represented the greatest fraction in the samples (62-94% of total PHCs). The PHC method is not suitable for quantitation of individual hydrocarbons (as for PAHs), which would require separate methods (CCME 2001a).

Trends in total PHCs from 2010 to 2015 is shown in Figure 6B; PHCs were not measured in the 2002/2003 study. Concentrations were stable or decreasing since 2010 with the exception of site LC03 which increased in 2015 by 1.9-fold, following a similar trend as other sediment contaminants (e.g., PCBs, PAHs).

3.3.3 Trace metals

In 2015, metals followed a similar pattern as other contaminants with concentrations peaking at LC03 followed by overall declines with distance downstream to LC38, where concentration were similar to the upstream site LC01 (Figure 7). Metal concentrations were mostly elevated from LC03 to LC18 in LCE compared to neighbouring reference creeks (Table 6). Five metals – As, Cu, Fe, Ni and Zn, were consistently elevated above low SQG TELs from LC03 to LC22 or LC38; whereas Cd, Cr, Pb and Hg exceeded at one or two sites (LC03 and LC12) (Table 6). Upstream site LC01 had concentrations below TELs for all metals except Cu and Fe, which just marginally exceeded. Between the low and high guidelines is the range where adverse effects may occasionally occur (CCME 1999a; MacDonald et al. 2000). Exceedences of high SQGs (PEL or SEL) occurred at LC03 for As (37.6 µg/g), Fe (7.2%), Pb (94 µg/g), Ni (131 µg/g) and Zn (4,290 µg/g), and from LC03 to LC22 for Zn (379-4,290) (Table 6).

Trends in concentrations of 8 individual metals from 2002 to 2015 for co-located sites are shown in Figures 8A (As, Cd, Cr, Cu) and 8B (Hg, Ni, Pb, and Zn). Similar to other contaminants, metals have remained mostly stable or in some cases declined since 2002 (increases observed in 2010 were followed by declines in 2015) with the exception of site LC03, which showed increased concentrations of all metals in 2015 (Figures 8A, 8B).

3.3.4 Nutrients

In 2015, TOC ranged from 3.7 to 8.5% (median 5.1%), TKN from 2,850 to 9,280 µg/g (median 6,167 µg/g), and TP from 863 to 3,290 µg/g (median 1,090 µg/g) in LCE (Table 6). Concentrations of TKN and TOC peaked at LC08 followed by a sharp decrease at LC12 after which they remained generally to LC38 whereas TP peaked at LC03 while remaining sites throughout the creek were 3 times lower (Figure 9). Comparatively, neighbouring reference site nutrient concentrations were lower (TP) or lower with some overlapping ranges (TOC, TKN) (Figure 9). Reference site TOC ranged from 3.3 to 5.3% (median 4.5%), TKN from 2,030 to 5,030 µg/g (median 3,150 µg/g), and TP from 548 to 953 µg/g (median: 773 µg/g), and (Table 6). Tee Creek was the most similar to LCE with respect to sediment nutrient levels.

Trends in sediment nutrients from 2002 to 2015 are shown in Figure 10. TOC increased or decreased over time depending on the site and remained consistently between the LEL and SEL across sampling years. Sediment TKN concentrations mostly decreased in 2010, except for LC08 which showed a considerable increase, after which concentrations were relatively stable to 2015 (Figure 10). Total P was mostly stable throughout the time period with the exception of 4 sites where increases occurred in 2010 to at or above the SEL followed by reverses in 2015 (e.g., LC08 to LC18) (Figure 10). Similar to sediment contaminants (e.g., PCBs, PAHs, metals), TP concentrations increased sharply from 2010 to 2015 to above the SEL at LCO3 whereas this was not as evident for TOC and did not occur for TKN (Figure 10).

3.4 PCB Bioaccumulation in Benthos

3.4.1 Bioaccumulation of PCBs in 2015

From 1 to 3 benthic taxa were collected for PCB analysis. The choice of taxa collected was based on high abundance and what was collected in previous surveys to allow for comparison. Concentrations of total PCBs in the benthos ranged from 207 to 5,140 ng/g dw for LCE and from 93 to 945 ng/g dw for the neighbouring reference creeks (Tables 7A-B). Similar to sediment, the tetra-chlorinated biphenyls were the dominant homologue group based on totals but individually, PCB 118 and PCB 105 dominated both the LCE and reference creek samples, followed by PCB 77 (Tables 7A-B). Where multiple taxa were collected at a site (e.g., LC16 to LC38, all 3 reference creeks), differences in PCB bioaccumulation between taxa within a site were 2.3-7.1-fold with the amphipods accumulating the highest levels (Tables 7A-B, Figures 11A-B). Concentrations of total PCBs and TEQs for the individual taxa are shown in Figures 11A and 11B, respectively. Total PCB concentrations peaked close to Highway 140 (site LC16 or LC18) followed by an overall decline to LC38 (Figure 11A). Benthos collected from upstream and downstream sites (LC01 and LC38) had PCB concentrations close to or below the 99th percentile for the reference sites, which was also found in previous studies (Milani and Grapentine 2006, 2014) while PCB tissue concentrations for the remaining LCE sites were ~3-9 times higher than the 99th percentile (Figure 11A). While sediment concentrations showed a large peak in total PCBs at LC03, taxa were not collected at this site for comparison due to the unsuitable substrate. The relationship between total PCBs in the sediment and biota was examined for amphipods only since there were too few data points for the other taxa collected.

There was a strong log-log relationship of TOC-normalized sediment PCBs versus lipid-normalized amphipod PCBs across sites (r^2 = 0.81, p=0.0004, n=10) (Figure 12); these results were similar to those found in previous surveys (Milani and Grapentine 2006, 2014).

The dioxin-like PCBs, expressed as TEQs, ranged from 1.7 to 273 pg TEQ/g ww for LCE and from 0.3 to 4.4 pg TEQ/g ww for reference creeks under the mid-point scenario (non-detects assigned ½ the detection limit) (Tables 7A-B). TEQs for amphipods were similarly elevated from LC08 to LC18 compared to reference then decreased with distance downstream to LC38; TEQs for the upstream and downstream sites (LC01, LC38) were similar or just slightly higher than those for reference sites (Figure 11B). For chironomids, TEQs were similar from Highway 140 to LC22 (Cooks Mills), while for oligochaetes, there was a decline from highway 140 to LC22 (Figure 11B). The TEQs were compared to an avian RC of 5.5 pg TEQ/g diet ww (see Section 2.6.2); exceedences of the RC occurred from LC08 to LC22 by 18-50 times (Figure 11B; Table 7A).

Bioavailability of individual dioxin-like PCB congeners were quantified by calculating biota-sediment accumulation factors (BSAFs). BSAFs reduce site variability due to differences in TOC concentration thus allowing for differences in contaminant bioaccumulation between species to be examined (Ankley et al. 1992). The BSAFs were calculated for dioxin-like congeners that were detected in both sediment and biota samples (paired samples); values > 1 indicates greater potential for the contaminant to accumulate in the tissues. For LCE, BSAFs ranged overall from 0.09 to 4.60 (mean: 1.04) and were overall higher for amphipods (mean: 1.29) compared to chironomids (mean: 0.86) and oligochaetes (mean 0.24) although there were more paired observations for amphipods (7 LCE sites versus 2-4 sites for the other taxa) (Appendix B, Table B4); 81% of paired amphipod-sediment observations were < 2 and the highest BSAFs were for the site located farthest downstream (LC38) where sediment contamination was lowest. BSAFs for reference creeks were higher than those for LCE, ranging overall from 0.63 to 19.59 (mean: 5.10); higher values for reference sites are typically seen where contamination in the sediment is low. These BSAFs for LCE were mostly similar to those reported by Richman and George (2014) for mayflies collected from the Spanish Harbour Area of Concern, where they ranged from 0.50 to 3.48. The BSAFs were calculated based on the integrated 0-10 cm of sediment; however, exposure of the organisms may not have been to 10 cm (e.g., amphipods may not penetrate that deep into the sediment). Thus it is possible that sediment PCB concentrations could be biased higher which would result in lower BSAFs. The BSAFs should therefore be interpreted with caution.

3.4.2 Temporal change in PCB bioaccumulation: 2002 to 2015

Trends in PCBs, expressed as total congeners (dw) and TEQs (ww) for amphipods collected from 2002 to 2015 are shown in Figures 13A and 13B, respectively. Total PCBs have remained mostly stable since 2002 or 2010 with the exception of sites at Highway 140 (LC16) to ~ 0.5 km downstream of the highway (LC18), (or 1.5-2 km from headwaters) where they increased over time (Figure 13A); a 1.7-2.7-fold increase was observed at these sites from 2002 to 2015. Site LC12 (1 km from headwaters), on the other hand, showed a 2.5-fold decrease since 2002 (Figure 13A). The TEQs followed a similar trend with overall increases at LC16 and LC18 from 2002 to 2015 but also showed increased concentrations at LC08 from 2002 (LC08 was not sampled for tissue in 2010) (Figure 13B). The increase in amphipod PCB TEQ at LC08, which did not follow that of total PCBs, was primarily driven by PCB-77, which was ~4-fold higher in 2015 than in 2002.

The mean concentration of total PCBs in amphipods collected from zones 1-5 (LC01-LC22) was relatively stable over the years – 3,342 ng/g dw in 2015 compared to 3,653 ng/g dw in 2002/2003 (Figure 14). In 2010, the mean concentration was lower at 2,980 ng/g; however, no data was available for 3 sites – LC08, LC18, and LC22 in this sampling year. A one-way ANOVA showed no significant difference in amphipod PCB concentrations (n=3-6 sampling points) between years within zones 1-5 ($F = 0.0006$, $p = 0.999$). Mean PCB concentration for amphipods collected from zones 1-4 were similar or slightly higher to those from zones 1-5 as there was the same number of sites in 2010 and only one less site in each of 2015 and 2002/2003 sampling years (mean total PCBs of 3,514 ng/g, and 3,964 ng/g, for 2015 and 2002/2003, respectively). While PCB concentrations in the amphipods of zones 1-5 have remained stable over time with likely some natural variation observed between years, they were nonetheless ~3.5 times higher than those observed downstream of zone 5 (e.g., LC38) or in reference creeks. These results are not unexpected given the low sedimentation rate identified for LCE of 1 mm/year (Golder Associates, 2008). With this accumulation rate, only ~ 13 mm of sediment accumulation would have occurred in the time span. The long term monitoring would need to consider the low sediment accumulation rate for LCE in order to manage recovery expectations.

3.5 Benthic Invertebrate Community Composition

3.5.1 Benthic community in 2015

Benthic communities in LCE in 2015 were dominated by the oligochaete worm, Naididae, or the midge Chironomidae, with both families present at all sites (Table 8; Figure 15A). Note: Naididae includes the former oligochaete family Tubificidae, which has been reclassified as subfamily Tubificinae under family Naididae (Erséus et al. 2008). Naidids comprised 4-95% of the total abundance at LCE sites and 14-76% at neighbouring reference creek sites. Overall, the mean number of naidids in LCE was 6,286 m^{-2} and they were most abundant from ~ 10 to 80 m from the headwaters (LC01 to LC03) (Figure 15A; Table 8). Naidids consisted mostly of unidentifiable immature Tubificinae, which comprised 75-80% of total naidid abundance (Appendix C, Table C1) and was also the most abundant taxon in 2 of the 3 neighbouring reference creeks (overall mean: 9,922 m^{-2}) (Figure 15B, Table 8). A total of 19 oligochaete species were identified in LCE, with *Limnodrilus hoffmeisteri* (LC03) or *Limnodrilus udekemianus* (LC01) numerically dominant in the upper creek followed by *Quistadrilus multisetosus*. Site LC03 was the most densely populated with *L. hoffmeisteri*, which comprised 73% of species at this site. *L. hoffmeisteri* is a ubiquitous species that is known to be tolerant/adaptable and generally found in great abundance in organically enriched/polluted areas (Rodriguez and Reynoldson 2011). Site LC01 (upstream of LC03) had lower worm abundances and was richer in worm species (14 species) compared to LC03 (4 species) and remaining LCE sites (3-5 species) (Appendix C, Table C1). At ~ 0.5 to 3.5 km from headwaters (LC08 to LC22), worm densities were substantially lower than upstream (1-2 orders of magnitude less) with *Aulodrilus pigueti* and *L. hoffmeisteri* dominating, while samples from farthest downstream (~11 km; site LC38) were comprised mostly of *A. pigueti* with *Ilyodrilus templetoni* (Appendix C, Table C1). Reference creeks had 4-12 worm species identified, with mostly *A. pigueti* with *L. hoffmeisteri* present (Appendix C, Table C1).

Chironomids were the next most abundant taxon in both LCE and reference sites, with overall means of 2,317 m^{-2} and 3,652 m^{-2}, respectively (Figures 15A-B). Chironomids comprised 2-52% of the total abundance for LCE sites and 7-56% for the reference sites. In LCE, they were less abundant at ≤ 0.5 km from headwaters (LC01-LC08) (≤ 663 m^{-2}), compared to ≥ 1 km (1,347 - 6,675 m^{-2}) with a peak in abundance at LC12 (Table 8). The dominant species of chironomids varied along the length of LCE; *Polypedilum halterale* (LC01 and LC08) or *Dicrotendipes* (LC03) in the upper 0.5 km, *Procladius* followed by *P. halterale* from 1 to 3.6 km and *Tribelos jucundum* followed by *Procladius* at 12 km (LC38) (Appendix C, Table C1). Two of the three reference creeks (Tee, Beaver) were similar to the LCE downstream reference site (LC38), dominated by *T. jucundum*, followed by *Procladius* whereas Usshers Creek was dominated by *Procladius* (Appendix C, Table C1). Other major taxon groups present at ≥ 5 sites in LCE included amphipods (2 families; 101-1,448 m^{-2}), mayflies (4 families; ≤ 471 m^{-2}), caddisflies (5 families; ≤ 353 m^{-2}), mites (6 families; ≤ 261 m^{-2}), pisidiid clams (≤ 1320 m^{-2}), ceratopogonid dipterans (≤ 3,780 m^{-2}), gastropods (5 families; ≤ 422 m^{-2}), and glossiphonid leeches (≤ 60 m^{-2}) (Table 8). These 10 families made up 68-99.5% of the total abundance found at LCE sites and 89-98% at reference sites; remaining families present occasionally (at 1-3 sites) are provided in Appendix C, Table C2. Total abundance ranged from 3,424 to 32,207 m^{-2} for LCE sites compared to 6,600 to 27,503 m^{-2} (mean: 16,304 m^{-2}) for reference creeks (Table 8).

Taxon richness (number of families) ranged from 6 to 21 in LCE; half the LCE sites had fewer families than that found in reference creeks, which ranged from 16 to 24 (Table 8). The fewest number of taxa (6 families) occurred at Cooks Mills' site LC22, located ~ 3.6 km downstream from the headwaters. It should be noted that amphipods (gammarid and/or hyalellid) were not found in the core or Ponar samples collected from LC01, LC22, LC38 and Usshers Creek reference site UC01, but were present at these sites when collected by sweep net for PCB congener analysis (see Section 2.2). The sampling device is important in LCE where amphipods are more likely found within the macrophytes beds, and taxon richness was therefore underestimated by 1 or 2 taxa at the 4 sites listed above.

While the species of worms (and chironomids) present at a given site can provide important information when assessing response to anthropogenic disturbance, the current site assessments were based on the entire community, which provides a richer amount of information (Rodriguez and Reynoldson 2011). The ordination (NMS) of 2015 LCE community site data is presented in Figure 16A. We chose to interpret a significant (randomization test p = 0.024) 2-dimensional NMS solution with a final stress of 4.54 after verifying consistency of interpretation among several NMS solutions. The association of families with a combined r^2 ≥ 0.45 are shown as vectors in Figure 16A, and the individual site counts for these families are provided in Table 8. Correlation coefficients with each individual axis for all families used in the assessment are provided in Appendix D, Table D1. Note: the cutoff of 0.45 was based on the r^2 relative to a combination of the axes being viewed as opposed to comparing the cutoff to the r^2 of the variable against scores of either axis (McCune and Mefford 2011). The combination of axes r^2 would include variables that are correlated to the pattern of the sample scores in the direction between the 2 axes, which is just as significant as variables correlated with either of the axes. Sites showed a strong gradient pattern along axis 1, with increasing abundance of naidids (r^2= 0.87) and decreasing abundance of several taxa including chironomids (r^2=0.79), hyalellids (r^2=0.51), caenid mayflies (r^2= 0.49), and hydrodromid mites (r^2=0.49) with increase in axis 1 (Figure 16A). Sites associated with increased naidids included those in upper creek (LC01 and LC03) and the Usshers Creek reference site (UC01), which were similar in composition (close proximity in ordination space), while sites associated with increased chironomids and the 3 other taxa listed above (and decreased naidids) were those at or just downstream of Highway 140 (LC16 and LC18) and the Tee Creek reference (TC01) (Figure 16A). Site LC08 (~0.5 km downstream from headwater) was distinct from the other sites, showing a separation on the second axes due primarily to increases in asellids (r^2= 0.84), gammarids (r^2= 0.82), valvatids (r^2= 0.79), glossiphonids (r^2= 0.67), and pisidiids (r^2= 0.46) (Figure 16A). The patterns for multiple explanatory (environmental) variables are shown in Figure 16B; those variables with $r^2 \geq 0.20$ (based on combined r^2 values) are shown as vectors and the correlation coefficients for all variables with each axis is provided in Appendix D, Table D2. Several metal oxides, nutrients (TKN, TOC), particle size (clay, sand), and PAHs may have had some influence over the response and these variables, with the exception of TOC, were most strongly correlated with the first axis (Figure 16B). PCBs (based on individual dioxin-like congeners, total congeners, and TEQs), were weakly correlated with individual axes ($r^2 \leq 0.076$; Appendix D, Table D2). The upper creek sites (LC01, LC03) were generally coarser (less clay, more sand) and were associated with increased PAHs (r^2 = 0.25). TOC was more strongly correlated with the second axis (r^2 = 0.22) and increased TOC was associated with site LC08 (Figure 16B). Site LC08 had the highest TOC (8.5%; Table 6), but TOC was also elevated at LC03 (7.9%) compared to rest of the creek and reference creeks (see Section 3.3.2).

The location of 2015 LCE sites in the same ordination space were also compared to 95% prediction intervals (PIs) computed for each axis using the 2015 neighbouring reference creek site scores. All LCE sites except LC08 fell within the PIs (Figure 16C). Site LC08 was the most dissimilar to reference, and was separated from the rest of the LCE sites along the second axis due to combined increases of several taxa, including asellids, gammarids and valvatids (Figure 16A); site LC08 also had lower taxon richness (9 families) compared to most other LCE sites and reference sites (Table 8). The PI along the first axis was comparatively large, due to high variability among reference site scores, and overlapped all LCE site scores (Figure 16C).

3.5.2 Temporal change in benthic community: 2002 to 2015

For the examination of trends in whole community composition from 2002 to 2015 for the co-located LCE sites, a 3-dimensional NMS solution was obtained (final stress = 10.26, p = 0.004). A polygon enclosed all sites within each of the three year groups to show if and how groups differed (Figure 17A). Families with combined axes $r^2 \geq 0.4$ are shown as vectors in Figure 17A and the correlation coefficients for all families with each individual axis provided in Appendix D, Table D3. The 2010 and 2015 groups were fairly similar, showing overlap along the axes with shift up on the second and third axes (from negative to positive) in 2015 from 2010 due primarily to increases in certain taxa (e.g., Naididae and Pisidiidae) (Figure 17A). The 2002 group was more dissimilar to 2015 than 2010 (less overlap) with a negative shift along the first axis from 2002 to 2010 and 2015 corresponding to decreased abundances of predominantly Chironomidae ($r^2 = 0.77$), Hyalellidae ($r^2 = 0.64$), Coenagrionidae (damselflies) ($r^2 = 0.55$), and Caenidae ($r^2 = 0.55$) (Figure 17A). On the second and third axes, the shift corresponded to increased Naididae ($r^2 = 0.53$), and Pisidiidae ($r^2 = 0.49$), respectively (Figure 17A, Appendix D, Table D3). Figure 17B shows the overlay of the explanatory (environmental) variables (as vectors) that had r^2 values (based on combined axes) ≥ 0.30. Variables that were most highly correlated with axis 1 included overlying water temperature ($r^2 = 0.51$) and total ammonia ($r^2 = 0.42$), while sediment TKN ($r^2 = 0.47$), overlying water NO_3+NO_2 ($r^2 = 0.35$) and sediment Al_2O_3 ($r^2 = 0.31$) were most highly correlated with axis 2, and TOC ($r^2 = 0.37$) to axis 3 (Figure 17B, Appendix D, Table D4). Similar to that seen above in the assessment of 2015 data only, results do not indicate the influence of PCBs; PCBs (based on total congeners and TEQs), were weakly correlated with axes ($r^2 \leq 0.065$; Appendix D, Table D4).

Based on the MRPP, a significant difference in community composition was found between the three year groups (p = 0.003), although the size of the difference was small given the high amount of within-group heterogeneity (A = 0.06) (Appendix E, Table E1). Pairwise comparisons indicated a difference for 2002 vs. 2010 (p = 0.004) and 2002 vs. 2015 (p = 0.002), while no difference was detected for 2010 vs. 2015 ($p = 0.96$) (Appendix E, Table E1). To explore which families were responsible for the observed differences between 2002 and subsequent years, Indicator Species Analysis (ISA) was conducted, followed by Monte Carlo randomization test to provide the statistical significance of the observed maximum Indicator Values (IVs). ISA determined which families were most constant and abundant in the groups that have been found to differ in composition. The IVs and the Monte Carlo randomization test results are provided in Appendix E, Table E2. About 76% of families were found to be more constant and abundant in 2002 compared to subsequent years. Families with significant maximum IVs were those from 2002 and included Chironomidae ($p = 0.0002$), Hyalellidae ($p = 0.02$), Naididae ($p = 0.03$), Coenagrionidae ($p = 0.04$), Plagiostomidae and Planariidae (flatworms) ($p = 0.001$-0.02), and Polycentropodidae (caddisfly) ($p = 0.03$) (Appendix E, Table E2). This indicated that these families were likely largely responsible for the observed group differences due to the larger relative abundance and frequency found in 2002 compared to 2010 and 2015 but that conditions in 2015 were fairly similar to those in 2010.

Trends were also examined for four commonly used community descriptors - total benthos, taxon richness, Pielou's evenness and Shannon's diversity index (Figures 18A-D) and five numerically important taxa – naidids, chironomids, amphipods, mayflies and caddisflies (Figures 19-23). Total benthos counts in LCE have decreased overall since 2002, although sharp declines observed at a few sites in 2010 (e.g., LC12, LC38) showed reverses in 2015; remaining sites, including those in the neighbouring reference creeks, have mostly remained stable since 2010 (Figure 18A). Taxon richness (number of families) showed some declines in 2010, followed by reverses in declines in 2015 at both LCE and reference sites (Figure 18B). Richness in LCE has remained relatively stable since 2002 except for sites LC01 and LC08 which showed multiyear declines, and LC22, which showed a sharp decline from 2002 (Figure 18B). (There are no data for LC22 in 2010.) Evenness is a measure of how individuals in a sample are distributed among taxa where 1 indicates all taxa have the same number and the closer to 0 the more uneven the numbers among taxa. Evenness has remained relatively stable in LCE since 2002 except for sites in the upper reach of the creek (LC01, LC03), where they have decreased since 2002, and remained below the lower range for the reference sites (Figure 18C). Shannon's diversity index is a measure of diversity in the community that takes into consideration both the relative abundance of taxa that are present and 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. Trends in diversity were similar to evenness and were generally stable overall except for sites in the upper reach (LC01, LC03), where multiyear declines were evident (Figure 18D).

Densities of naidid worms generally followed a similar trend as total benthos (Figure 19). Most LCE sites (5 of the 8) showed overall declines since 2002, while only 1 of the 3 reference sites showed declines (Figure 19). Some reverses in declines were seen, however, from 2010 to 2015 (e.g., sites LC12 and LC38) (Figure 19). Worm densities at site LC03 were consistently above the range at reference sites over the time period (Figure 19). Chironomids also showed overall declines from 2002 to 2015, with some reverses seen at the same sites that also showed reverses in naidids (LC12 and LC38) from 2010 to 2015 (Figure 20). Overall declines were also observed at reference sites, although densities were fairly stable from 2010 to 2015. About half the LCE sites were below the reference range from 2010 to 2015, mostly from LC01 to LC08 (Figure 20). Trends in amphipod densities would be difficult to interpret at sites where they were absent from samples collected with cores tubes or grabs but present in the sweep samples (i.e., LC01, LC22 and LC38, UC01) or where sweeps were not conducted (i.e., LC03) - these 5 sites were therefore removed from examination of trends over time. Amphipod densities have remained generally stable over time, but fluctuated, with declines in 2010 followed by reverses in 2015; densities for LCE were within or above the range at reference sites over the entire time period (Figure 21). Mayfly densities were variable over time with 6 of the 8 LCE sites showing overall decreases since 2002; however, since 2010 densities have remained mostly stable except for site LC08 which showed a sharp decline in 2015 (Figure 22). Densities of mayflies at about half the LCE sites were below those at reference sites, where densities were fairly stable since 2002 or 2010 (Figure 22). Caddisfly densities have declined overall since 2002 at 5 of the 8 sites but have remained stable or increased since 2010, except for site LC22 (Figure 23). Site LC08, which showed declines in mayflies in 2015 showed an increase in caddisflies in 2015 (Figure 23).

3.6 Sediment Toxicity

3.6.1 Toxicity conditions in 2015

Survival, growth and reproduction of invertebrates in the laboratory bioassays conducted with 2015 LCE and neighbouring reference sediments are provided in Table 9. For each endpoint, potential toxicity and toxicity, based on responses differing by minus 2 and 3 SDs from the mean of 66 GL reference sites, are highlighted blue and red, respectively. There was reduced survival in the upper reach of the creek from LC03 to Highway 140 (LC16) for 1-3 test organisms (Table 9): *Hyalella* (28-61% survival) *Hexagenia* (0-84% survival), and *Chironomus* (73% survival). *Tubifex* cocoon production (2.2-7.8/adult), percent of cocoons hatched (24-32%) and young production (1.1-6.1/adult) were also reduced compared to GL reference at several sites in the upper creek, but also the downstream location (LC38) and in Beaver Creek (reference) (Table 9).

Using the 10 toxicity endpoints, a 2-dimensional NMS solution was obtained for the GL reference data (final stress = 12.30, p = 0.004). The LCE and neighbouring reference creek sites (n=10) were fitted into the NMS space one at a time and probability ellipses constructed around the reference sites. The outcomes (Figure 24) were the following overall toxicity assessments:

Toxicity Band	Site
Non-toxic	LC01, LC12, LC18, LC22, TC01
Potentially toxic	BEC02
Toxic	LC08, LC38
Severely toxic	LC03, LC16

Overall, survival of the amphipod *Hyalella* and mayfly *Hexagenia* were most affected, with toxicity most severe from 80 to 500 m downstream from the headwaters of the creek. Chronic toxicity to the worm *Tubifex* occurred in areas of high contamination (upper 500 m of the creek) as well as low/no contamination (downstream and reference creek), although the most severe worm toxicity was coincident with acute toxicity to other test organisms (e.g., sites LC03 and LC08) (Table 9). While *Tubifex* reproduction was affected in laboratory tests, LCE and reference creeks support a good worm population (Table 8) and the sites with the lowest worm densities (LC16 and LC18) did not exhibit toxicity in the laboratory bioassays (Table 9). The severe toxicity at LC03 (which scored the farthest away from the reference centroid in ordination space) and toxicity restricted to the upper reach of the creek (upstream of Highway 140) was consistent with past studies (Milani and Grapentine 2006; Milani et al., 2013).

3.6.2 Temporal change in toxicity from 2002 to 2015

For the examination of trends in toxicity from 2002 to 2015 for the co-located LCE sites, we chose to interpret a significant (randomization test $p = 0.004$) 2-dimensional NMS solution with a final stress of 10.53 after verifying consistency of interpretation among several NMS solutions. Polygons were used to enclose sites within each of the three groups that were represented by sampling years 2002, 2010 and 2015 to discern if and how groups were separated (Figure 25A). Endpoint r^2 values relative to combined axes that were ≥ 0.4 are shown as vectors and the correlation coefficients for endpoints with each individual axis is provided in Appendix F, Table F1. The 2010 and 2015 groups were fairly similar to each other, showing overlap on both axes, while the 2002 group was more distinctly different from the successive groups (Figure 25A). A shift from 2002 to 2010 and 2015 groups was most notable on the second axis, which corresponded to a decrease in *Tubifex* toxicity (increased *Tubifex* cocoon hatching) in 2010 and 2015 (Figure 25A). Figure 25B shows the overlay of the explanatory (environmental) variables with r^2 values (based on combined r^2 values for both axes) ≥ 0.4 shown as vectors. Contaminant variables were generally most correlated with the first axis and included the metals Pb, Cu, Ni, Zn and Cr and total PCBs with increased concentrations of these contaminants associated with sites in the upper creek (e.g., LC03, LC08, and LC12) (Figure 25B) in all years. Increased PAHs (also shown as a vector) as well as PCBs appears to be more associated with sites in the upper reach of the creek in 2010 and 2015 (Figure 25B), which was also noted in Figures 3 and 6 (PCB and PAH concentrations through time, respectively).

Trends in individual toxicological response for co-located sites sampled from 2002-2015 are shown in Figures 26-29. Eight of the 10 endpoints showed mostly stable or increasing trends since 2002 or 2010 with only *Hyalella* growth and *Tubifex* cocoon production showing declines. *Hyalella* growth declined at both LCE and the neighbouring reference sites from 2010 to 2015, to below the GL mean but within -2 SD of the mean with the exception of sites LC03, LC08 and LC16 (Figure 26B). *Hyalella* survival did not follow this same trend, remaining stable since 2002 with the exception of LC16, which showed a sharp decline from 2010 to 2015 (Figure 26A). *Tubifex* cocoon production declined at about half the sites from 2010 to 2015 (Figure

29B); however, the 2 other reproduction endpoints either increased (cocoon hatching) or were stable or increasing (young production) over time (Figures 29C-D).

4 CONCLUSIONS

The 2015 assessment of benthic conditions in Lyons Creek East represents the second sampling effort undertaken since Monitored Natural Recovery (with administration controls) was chosen in 2008 as the best approach to manage the contaminated sediments. The purpose of the 2015 survey was to determine if, and by how much, benthic conditions were recovering compared to a similar survey conducted in 2002/2003 as the baseline. This study addressed a main component of the governments of Ontario and Canada's long term monitoring plan - the bioaccumulation of PCBs in native benthos and provided information on surficial (0-10 cm) sediment contamination. Benthic invertebrate community structure and sediment toxicity were also assessed providing supplemental information on recovery progress. Conditions in the creek in 2015 were compared to those from reference sites (local or regional) and to targets set by the governments. Temporal trends were examined from 2002 to 2015.

Consistent with the past studies, contamination and effects were most severe in the upper reach of the creek from Ridge Road to Highway 140. A summary of status and trends are presented in Table 10. Sediment and benthos total PCB concentrations remained elevated in the creek compared to neighbouring reference creeks and were above sediment quality guidelines or a tissue Reference Concentration from Ridge Road to ~ 3.6 km from the headwaters of the creek (at Cooks Mills). Concentrations of total PCBs in the sediment have remained stable since 2002 with the exception of the site at Ridge Road where high concentrations were found in 2015. Previous sampling at the Ridge Road location showed much lower concentrations, which could reflect small scale heterogeneity for this area with the 2015 site representing a local hot spot for this part of the upper creek. Other contaminants (e.g., metals, PAHs, petroleum hydrocarbons) had similar or higher concentrations compared to reference, and were mostly stable or decreasing over time except for the site at Ridge Road in 2015. Invertebrate total PCB concentrations have remained stable or decreased since 2002 or 2010 with the exception of sites close to or just downstream of Highway 140, where increases were observed in 2015. Mean PCB levels in invertebrates from zones 1 to 5 showed no significant change over time.

In 2015, whole benthic communities in Lyons Creek East were fairly similar to those from neighbouring creeks except for one site in the upper reach of the creek (0.5 km from headwaters), which was different due to increased densities of several taxa including amphipods and lower taxon richness. Individual community descriptors (e.g., total benthos, taxon richness) were mostly similar or lower than reference whereas others (e.g., evenness and diversity) were more variable. Densities of predominant benthic families found in Lyons Creek East were mostly similar or lower than those for reference creeks. Over time, benthic communities as a whole appeared stable since 2010. Acute sediment toxicity was restricted to areas upstream of Highway 140 in 2015, where 1 to 3 test organisms were affected. Over time, individual endpoint responses (survival, growth, and reproduction) have mostly remained stable.

Overall, this study showed that conditions in the creek have remained relatively stable since 2002 or 2010. PCB levels in native benthos, however, remain elevated along the creek. The long term monitoring plan will need to take into account the low sediment accumulation rate for Lyons Creek East in order to manage recovery expectations.

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TABLES

Table 1. Lyons Creek East and reference creek site coordinates and visual descriptions for sediment samples collected in 2015.

Creek	Zone	Site	~ distance from headwaters (km)	Sampling Device	Latitude	Longitude	Description
Lyons East	1 (u/s)	LC01	0.01	Petite Ponar	42.974050	-79.220767	Brown silty mud with some sand
Lyons East	1	LC03	0.08	Benthic Core	42.974550	-79.220200	2 cm of brown silt over tarry, smelly black organic mud - oily
Lyons East	2	LC08	0.5	Benthic Core	42.976750	-79.216517	Brown organicy mud - very smelly and tarry. Mud is very liquidy. Oil sheen and tar visible when sediment is
Lyons East	2	LC12	1.0	Benthic Core	42.977550	-79.210317	Very smelly - brown organicy mud - fine lighter brown silt over silty organic mud.
Lyons East	3	LC16	1.5	Petite Ponar	42.980183	-79.205767	1-2cm light brown silt over silty organic mud. Lots of macrophytes present.
Lyons East	4	LC18	2.0	Petite Ponar	42.983450	-79.201117	Fine brown silty mud. Light brown silt (1-2cm) over silty mud with macrophytes present.
Lyons East	5	LC22	3.6	Benthic Core	42.991983	-79.185675	Soft brown mud. 1-2cm of light brown silt over darker mud. Hydrocarbon odour.
Lyons East	d/s Ref	LC38	12	Petite Ponar	43.034100	-79.096067	1-2cm of light brown silt over brown silty fine sand with organics - organicy mud.
Tee	Ref	TC01	-	Petite Ponar	43.030983	-79.111083	Soft mud with some gravelly spots - macrophytes present.
Usshers	Ref	UC01	-	Benthic Core	43.050033	-79.022250	Organicy mud with lots of vegetation over coarser sandy mud. Softer mud found in the emergent
Beaver	Ref	BEC02	-	Petite Ponar	42.956933	-79.033083	Samples taken close to macrophytes. Brown silty mud with organics and some coarse sand.

Table 2. Environmental variables measured at 2015 Lyons Creek East and neighbouring reference creek sites.

Field	Water	Sediment	Benthic Invertebrates
Latitude	Alkalinity	PCB congeners	PCB congeners
Longitude	Conductivity	Trace metals/metal oxides	
Site Depth	Dissolved Oxygen	PAHs	
	pH	Petroleum Hydrocarbons	
	Temperature	Total Phosphorus	
	Total Kjeldahl Nitrogen	Total Kjeldahl Nitrogen	
	Total Phosphorus	Total Organic Carbon	
	NH_3-N,	Loss on Ignition	
	NO_3/NO_2-N	Clay, Silt, Sand, & Gravel	

Table 3. Concentrations of dioxin-like PCBs (pg/g dw), total PCB congeners (ng/g dw) and PCB toxic equivalents (pg TEQ/g ww) for sediments collected from Lyons Creek East and neighbouring reference creeks in 2015. Values above the Probable Effect Level based on total PCBs (277 ng/g) and toxic equivalents (TEQs) (21.5 ng TEQ kg^{-1} dw) are highlighted red. The toxic equivalency factors for fish were used in the calculations of the TEQ (see text for details). LC = Lyons Creek, TC=Tee Creek, BEC=Beaver Creek, UC= Usshers Creek.

	LC01	LC03	LC08	LC12[a]	LC16	LC18	LC22	LC38	TC01[b]	UC01	BEC02
Dioxin-like PCBs	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
PCB 81	<130	17300	<1800	<9400	412	<190	<75	<59	<50	<0.72	<12
PCB 77	441	368000	16100	41433	15200	7300	3890	125	130	6.7	34.4
PCB 126	<62	<7500	<720	1385	570	322	192	<17	14.4	<8.0	9.4
PCB 169	<15	<970	<190	<210	<58	37	<38	<4.9	<3.6	<4.2	<2.3
PCB 105	1530	1E+06	59600	136567	44100	22000	9560	366	342	<44	216
PCB 114	<80	67200	<2300	6170	3390	1560	616	<8.3	<6.9	<6.5	<10
PCB 118	3410	2E+06	98400	235333	81700	40700	18900	961	920	90.4	548
PCB 123	154	45400	<3200	13565	2570	1470	565	<8.6	<7.3	<6.8	<5.6
PCB 156/157	218	77100	4530	10843	4310	2070	1420	90.4	68	12.2	59.1
PCB 167	83.4	22200	1610	3296.7	1430	657	500	32.7	28.3	<4.4	20.3
PCB 189	<24	4660	<380	770	323	142	220	<7.4	9.945	<6.4	5.06
Homologue Group Totals	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
Total MonoCB	20.2	32.5	0.626	2.13	1.33	0.436	0.244	0.0541	0.0746	0.0083	0.0592
Total DiCB	1.47	3670	32.5	205.3	49.2	22.2	11.2	0.721	1.182	0.0483	0.15
Total TriCB	14.1	26500	362	2336	533	293	135	6.38	10.35	0.135	0.893
Total TetraCB	52.7	43300	1610	5380	1730	842	371	11.8	15.8	0.398	1.96
Total PentaCB	31.1	15600	1040	2013	728	352	162	6.99	7.195	0.503	3.47
Total HexaCB	9.1	2840	228	379	157	77.3	90.5	4.54	4.48	0.549	2.75
Total HeptaCB	4.17	1080	86.7	119.1	55.9	26.1	50	1.84	2.24	0.275	0.908
Total OctaCB	1.36	237	21.1	38.2	16.5	7.72	11.9	0.532	0.673	0.108	0.329
Total NonaCB	0.229	31.1	3.23	5.79	2.6	1.15	1.06	0.123	0.138	0.0389	0.12
DecaCB	0.042	2.48	0.33	0.54	0.275	0.132	0.143	0.0668	0.0709	0.0236	0.0929
Total PCB (ng/g)	**134**	**93200**	**3380**	**10487**	**3270**	**1620**	**833**	**33.0**	**42.2**	**2.1**	**10.7**
Toxic Equivalency	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
Lower Bound PCB TEQ (WHO 1998)	0.071	**59.5**	2.43	13.07	5.27	2.68	1.51	0.020	0.092	0.001	0.055
Mid Point PCB TEQ (WHO 1998)	0.259	**78.3**	4.70	14.40	5.27	2.73	1.53	0.077	0.103	0.022	0.058
Upper Bound PCB TEQ (WHO 1998)	0.447	**97.1**	6.97	15.74	5.27	2.78	1.55	0.135	0.114	0.042	0.061

[a] values represent mean of 3 field-replicated samples; [b] value represents mean of lab duplicate sample

Table 4. Concentrations of sediment PAHs (µg/g dw) for 2015 Lyons Creek East and neighbouring reference creeks. Values in blue and red exceed the Threshold Effect Level (TEL) and Probable Effect Level (PEL), respectively. LC= Lyons Creek, TC=Tee Creek, BEC=Beaver Creek, UC= Usshers Creek.

	UNITS	TEL	PEL	LC01	LC03	LC08	LC12[a]	LC16	LC18	LC22	LC38	TC01	BEC02	UC01
Polyaromatic Hydrocarbons														
Acenaphthene	ug/g	0.0067	0.0889	0.052	**1.4**	<0.03	0.050	<0.03	<0.03	<0.03	<0.015	<0.02	0.039	<0.01
Acenaphthylene	ug/g	0.0059	0.128	0.01	<0.3	<0.03	0.018	<0.03	<0.03	<0.03	<0.015	<0.02	0.12	0.077
Anthracene	ug/g	0.0469	0.245	0.029	**2.3**	0.054	0.110	0.037	<0.03	0.038	0.022	<0.02	0.24	**0.5**
Benzo(a)anthracene	ug/g	0.0317	0.385	0.11	**4.6**	0.19	0.307	0.12	0.084	0.1	0.059	0.03	**0.53**	0.25
Benzo(a)pyrene	ug/g	0.0319	0.782	0.11	**2.1**	0.21	0.260	0.14	0.11	0.11	0.076	0.034	0.43	0.21
Benzo(b/j)fluoranthene	ug/g			0.14	2.9	0.28	0.307	0.23	0.16	0.17	0.1	0.068	0.63	0.33
Benzo(g,h,i)perylene	ug/g	0.17[b]		0.066	1.7	0.19	0.197	0.14	0.1	0.065	0.061	0.037	0.19	0.11
Benzo(k)fluoranthene	ug/g	0.24[b]		0.041	0.63	0.072	0.072	0.058	0.034	0.036	0.024	0.019	0.18	0.1
Chrysene	ug/g	0.0571	0.862	0.098	**5.4**	0.23	0.377	0.17	0.13	0.09	0.081	0.04	0.64	0.19
Dibenz(a,h)anthracene	ug/g	0.0062	0.135	0.014	**0.32**	0.034	0.042	<0.03	<0.03	<0.03	<0.015	<0.02	0.055	0.031
Fluoranthene	ug/g	0.111	2.355	0.22	**17**	0.38	0.727	0.3	0.2	0.24	0.11	0.086	1.4	0.38
Fluorene	ug/g	0.0212	0.144	<0.05	**3.0**	<0.03	0.110	<0.03	<0.03	<0.03	<0.015	<0.02	**0.17**	<0.02
Indeno(1,2,3-cd)pyrene	ug/g	0.20[b]		0.075	0.7	0.14	0.120	0.1	0.09	0.077	0.052	0.035	0.28	0.15
1-Methylnaphthalene	ug/g			0.017	<0.3	<0.03	0.015	<0.03	<0.03	<0.03	<0.015	<0.02	0.037	<0.01
2-Methylnaphthalene	ug/g			0.11	<0.3	0.16	0.190	0.25	0.25	0.16	0.13	0.1	0.073	0.035
Naphthalene	ug/g	0.0346	0.391	0.016	<0.3	<0.03	0.020	<0.03	<0.03	<0.03	<0.015	<0.02	0.021	<0.01
Phenanthrene	ug/g	0.0419	0.515	0.11	<0.3	0.12	0.153	0.11	0.075	0.042	0.043	0.025	**0.97**	0.045
Pyrene	ug/g	0.053	0.875	0.17	**21**	0.45	0.760	0.26	0.18	0.17	0.099	0.067	**0.94**	0.34
Sum PAHs	ug/g	4[b]		**1.41**	**63.80**	**2.59**	**3.83**	**2.01**	**1.52**	**1.39**	**0.90**	**0.61**	**6.95**	**2.77**

[a] values represent mean of field-replicated samples; [b] Lowest Effect Level (TEL not available)

Table 5. Concentration of sediment total petroleum hydrocarbon (mg/kg dw) for 2015 Lyons Creek East and neighbouring reference creek sites. LC = Lyons Creek, TC=Tee Creek, BEC=Beaver Creek, UC= Usshers Creek.

ANALYTE	**LC01**	**LC03**	**LC08**	**LC12[a]**	**LC16**	**LC18**	**LC22**	**LC38**	**TC01**	**UC01**	**BEC02**
Benzene	<0.110	<0.110	<0.110	<0.110	<0.110	<0.110	<0.110	<0.110	<0.110	<0.110	<0.110
Ethylbenzene	<0.160	<0.160	<0.160	<0.160	<0.160	<0.160	<0.160	<0.160	<0.160	<0.160	<0.160
m,p-Xylenes	<0.330	0.960	<0.330	0.970	<0.330	<0.330	<0.330	<0.330	<0.330	<0.330	<0.330
o-Xylene	<0.130	<0.130	<0.130	0.920	<0.130	<0.130	<0.130	<0.130	<0.130	<0.130	<0.130
Toluene	0.850	0.320	2.560	0.990	0.840	0.400	0.380	0.910	0.490	0.760	1.100
Fraction 1 (C6-C10)	<10.2	<10.2	<10.2	<10.2	<10.2	<10.2	<10.2	<10.2	<10.2	<10.2	<10.2
Fraction 2 (C10-C16)	7.05	516	25.1	41.3	21.7	7.71	3.74	1.82	2.68	4.2	3.06
Fraction 3 (C16-C34)	213	21500	2730	2787	1570	762	511	83	60.7	99.8	98.7
Fraction 4 (C34-C50)	176	7350	1020	974	573	293	203	16.3	19.1	27.8	17.5
Fraction 4G (Gravimetric)	937	36400	6290	5813	3250	1860	2040	1310	1120	1110	1560
Total PHCs	**1157**	**58416**	**9045**	**8641**	**4842**	**2630**	**2555**	**1395**	**1183**	**1214**	**1662**

[a] values represent mean of field-replicated samples

Table 6. Concentrations of sediment metals and nutrients for 2015 Lyons Creek East and neighbouring reference creek sites. Values exceeding the Probable Effect Level (PEL) and the Threshold Effect Level (TEL) are highlighted in red and blue, respectively. LC = Lyons Creek, TC=Tee Creek, BEC=Beaver Creek, UC= Usshers Creek.

Parameter	Units	M.D.L.	TEL	PEL	LC01	LC03	LC08	LC12[a]	LC16[b]	LC18	LC22	LC38	TC01	UC01	BEC02
Aluminum	µg/g	10			11200	14800	14400	15633	17800	17700	18800	15400	17500	7080	11400
Antimony	µg/g	0.5			< 0.5	2.1	0.6	1	0.6	0.5	0.5	< 0.5	< 0.5	< 0.5	< 0.5
Arsenic	µg/g	0.5	5.9	17.0	5.2	**37.6**	**8.3**	**9.8**	**8.1**	**6.3**	**7.3**	4.7	5.5	2.5	4.0
Barium	µg/g	1			83	126	92	124	127	128	122	90	112	48	74
Beryllium	µg/g	0.2			0.6	0.8	0.7	0.8	0.8	0.8	0.9	0.8	0.8	0.4	0.6
Bismuth	µg/g	5			< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Cadmium	µg/g	0.5	0.6	3.5	< 0.5	**1.0**	< 0.5	**0.7**	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Calcium	µg/g	10			82600	33500	10300	38267	45150	31600	8140	9100	12200	11100	12400
Chromium	µg/g	1	37.3	90	20	**68**	32	35	34	30	32	25	27	12	18
Cobalt	µg/g	1			9	19	12	12	12	11	13	13	14	9	11
Copper	µg/g	1	35.7	197	**38**	**106**	**48**	**60**	**53**	**38**	**37**	25	27	12	24
Iron	µg/g	10	20000[c]	40000[d]	**22800**	**72400**	**28500**	**31967**	**33550**	**32400**	**33200**	**26300**	**30200**	**13100**	**18800**
Lead	µg/g	5	35	91.3	15	**94**	34	**45**	34	23	26	19	22	15	17
Magnesium	µg/g	10			15800	9590	9230	8477	10450	9160	8300	7620	8610	6480	8480
Manganese	µg/g	1	460[c]	1100[d]	508	463	253	292	369	348	360	323	530	219	216
Mercury	µg/g	0.005	0.17	0.486	0.043	**0.202**	0.076	0.116	0.096	0.076	0.083	0.107	0.115	0.035	0.063
Molybdenum	µg/g	1			< 1	5	1	1	1.0	< 1	1	< 1	< 1	< 1	< 1
Nickel	µg/g	1	16[c]	75[d]	**27**	**131**	**42**	**48**	**44**	**39**	**45**	**36**	**40**	15	**36**
Phosphorus	µg/g	5			782	4720	885	1008	993	853	916	848	858	577	716
Potassium	µg/g	30			2000	1920	2050	1973	2375	2220	2240	1820	1990	900	1620
Silver	µg/g	0.2			0.3	23.9	12.5	8.1	12	5.4	3.2	< 0.2	< 0.2	< 0.2	< 0.2
Sodium	µg/g	20			260	200	240	220	250	250	240	230	250	170	230
Silicon	µg/g	1			211	217	286	241	232	194	213	277	274	247	284
Strontium	µg/g	1			144	91	48	120	130	109	51	52	68	25	69
Tin	µg/g	5			< 5	12	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Titanium	µg/g	1			237	161	190	171	160	140	148	155	160	138	183
Vanadium	µg/g	1			24	33	29	30	32	31	34	28	31	19	24
Yttrium	µg/g	0.5			11.8	11.8	11.5	10.5	10	9.5	10.3	11.2	11.3	7.9	10.8
Zinc	µg/g	3	123	315	96	**4290**	**417**	**749**	**640**	**379**	**408**	**143**	**209**	67	88
Zirconium	µg/g	0.1			1.9	2.3	3.1	2.5	3.1	2.4	2.9	2.7	4.6	1.5	2.5
TC (LOI@1000°C)	%	0.05			17.4	19.5	21.2	18.5	19.6	17.2	16.5	14.9	15.7	7.36	9.68
Total Kjeldahl Nitrogen	µg/g	5	550[c]	4800[d]	**2850**	**3210**	**9280**	**6293**	**6730**	**6040**	**6830**	**5430**	**5030**	**2030**	**3150**
Phosphorus-Total	µg/g	1	600[c]	2000[d]	**863**	**3290**	**1080**	**1104**	**1100**	**1060**	**1170**	**1020**	**953**	548	**773**
Total Organic Carbon	%	0.1	1[c]	10[d]	**3.7**	**7.9**	**8.5**	**5.3**	**4.5**	**4.1**	**5.1**	**5.0**	**5.3**	**3.3**	**4.5**

[a] values represent mean of field-replicated samples; [b] value represents mean of lab duplicate sample [c] Lowest Effect Level (TEL not available); [d] Severe Effect Level (PEL not available)

Table 7A. Concentrations of dioxin-like PCBs (pg/g dw), total PCB congeners (ng/g dw) and PCB toxic equivalents (pg TEQ/g ww) for benthos collected from Lyons Creek East in 2015. Values exceeding an avian reference concentration of 5.5 pg TEQ·g^{-1} diet ww are highlighted red.

Site	LC01	LC08	LC12	LC16	LC16	LC16	LC18	LC18	LC22[a]	LC22	LC22	LC38	LC38
Taxon	AMPH	AMPH	AMPH	AMPH/ISO	CHIR	OLIG	AMPH	CHIR	AMPH	CHIR	OLIG	AMPH	CHIR
Dioxin-like PCBs	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
PCB 81	18.9	719	831	858	317	240	924	271	358	205	<58	13.6	<14
PCB 77	417	18100	25200	25600	10000	8980	24700	7810	9345	6590	1280	315	288
PCB 126	<36	488	485	472	179	<500	439	<2400	183	<140	<1200	<7.0	<9.8
PCB 169	<17	<35	<57	<41	30.8	<230	<14	<770	<42	<79	<510	4.07	<6.4
PCB 105	2630	62100	75900	73400	36200	38200	70900	15800	26350	17600	<6500	1650	1720
PCB 114	<190	4970	6180	6230	2400	2300	6160	<2100	1920	1530	<1100	116	<120
PCB 118	7130	1E+05	1E+05	1E+05	69100	64800	1E+05	43500	56900	36700	15600	5070	5160
PCB 123	<170	4970	5160	4930	1970	<460	4090	<2100	1625	1000	<1100	95.5	<7.5
PCB 156/157	312	5210	5950	4670	2660	3580	4960	<3000	2890	1840	<1700	237	247
PCB 167	132	1540	2100	1530	836	1150	1660	1760	1110	639	978	90	100
PCB 189	<14	<170	214	181	<460	238	177	<1100	205	236	<490	12.1	<16
Homologue Group Totals	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
Total MonoCB	0.84	0.888	0.607	1.36	0.29	0.348	1.36	0.492	2.26	0.349	0.331	1.84	0.346
Total DiCB	7.05	17	16.3	26.2	5.98	12.3	31.2	6.2	27.8	5.07	7.46	14.2	5.89
Total TriCB	48.8	292	377	560	120	102	654	85	362	108	31.7	101	20.5
Total TetraCB	151	1470	2320	2710	602	433	2920	353	1260	351	130	238	89.5
Total PentaCB	109	945	1290	1210	382	374	1280	189	577	221	92.2	103	67.6
Total HexaCB	23.6	200	253	195	80	92.7	202	64.4	173	81	49.5	18.1	17.4
Total HeptaCB	6.3	48.6	60.6	42.8	21	37.8	45.7	22.6	72.3	34.7	30.7	3.58	4.47
Total OctaCB	1.08	7.19	9.18	6.1	5.71	8.44	6.77	5.1	10.73	5.49	7.64	0.628	1.14
Total NonaCB	0.108	0.604	0.739	0.51	<460	0.899	0.542	<770	0.424	<130	<700	0.068	0.224
DecaCB	0.03	0.029	0.048	0.037	0.087	0.125	0.044	0.1	0.036	0.051	0.159	0.04	0.122
Total PCB	**349**	**2990**	**4330**	**4760**	**1220**	**1060**	**5140**	**726**	**2485**	**806**	**350**	**479**	**207**
Toxic Equivalency - (WHO 1998)	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
Lower Bound PCB TEQ	5.22	189	260	273	51.6	69.0	266	47.6	101	63.8	4.9	3.2	1.5
Mid Point PCB TEQ	5.23	189	260	273	51.6	72.6	266	61.3	101	65.1	9.7	3.3	1.7
Upper Bound PCB TEQ	5.23	189	260	273	51.6	76.2	266	75.0	101	66.4	14.6	3.3	1.8

[a] value represents mean of field duplicate sample

Table 7B. Concentrations of dioxin-like PCBs (pg/g dw), total PCB congeners (ng/g dw) and PCB toxic equivalents (pg TEQ/g ww) for benthos collected from neighbouring reference creeks in 2015. TC=Tee Creek, BEC=Beaver Creek, UC= Usshers Creek.

Site	**TC01**[a]	**TC01**	**BEC02**	**BEC02**	**BEC02**	**UC01**	**UC01**	**UC01**
Taxon	AMPH	CHIR	AMPH	CHIR	OLIG	AMPH	CHIR	OLIG
Dioxin-like PCBs	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
PCB 81	<13	<20	6.03	<1.9	<10	7.78	<24	<3.6
PCB 77	526	223	121	<55	<80	157	108	80.5
PCB 126	9.73	<20	<7.8	<14	<120	<8.2	<450	<93
PCB 169	<4.4	<18	<4.0	<6.9	<43	<4.5	<140	<31
PCB 105	2400	1310	917	713	572	911	<370	909
PCB 114	181	<99	77.7	<43	<120	<74	<350	<82
PCB 118	8030	3940	3220	2330	<1500	3080	1990	2540
PCB 123	178	82.2	60.8	<42	<120	66.2	<370	<80
PCB 156/157	215.5	173	98.2	137	<84	74.5	<160	<220
PCB 167	86.8	<65	37.2	<45	<37	<25	<110	162
PCB 189	19.5	22.8	<3.2	<9.6	<66	<5.6	<200	<34
Homologue Group Totals	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
Total MonoCB	1.96	0.522	1.18	0.104	0.197	1.57	0.427	0.07
Total DiCB	21.2	17.8	8.91	1.2	3.25	12.1	3.98	1.01
Total TriCB	187	16	60.7	11.9	7.29	84.5	12.2	10.2
Total TetraCB	488	76	143	60	37.3	199	54.7	40.8
Total PentaCB	211	58.5	72.5	49.2	34.8	85.7	43.2	37.4
Total HexaCB	29.6	13.4	11.9	11.7	8.07	12.1	8.18	16.6
Total HeptaCB	6.28	3.82	1.44	2.32	1.36	1.75	0.76	6.96
Total OctaCB	1.22	0.811	0.25	0.754	0.269	0.268	<98	1.93
Total NonaCB	0.103	0.101	0.043	0.296	<100	<7.6	<310	0.281
DecaCB	0.057	0.12	0.015	0.11	0.122	0.026	0.095	0.099
Total PCB	**945**	**187**	**300**	**138**	**93**	**397**	**123**	**115**
Toxic Equivalency - (WHO 1998)	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
Lower Bound PCB TEQ	4.240	2.067	1.576	0.497	0.593	1.366	0.014	0.006
Mid Point PCB TEQ	4.364	2.434	1.651	2.683	1.289	1.445	0.300	0.976
Upper Bound PCB TEQ	4.488	2.801	1.726	4.868	1.984	1.523	0.587	1.946

[a] value represents mean of field duplicate sample

Table 8. Predominant benthic macroinvertebrate family abundance (number m^{-2}) and richness for 2015 Lyons Creek East and neighbouring reference creek sites. The average (standard deviation (SD)) for the three reference creeks is also provided for comparison. Red 0-values indicate sites where amphipods were present but not found in core or Ponar samples. A complete list of counts are provided in Appendix C. LC = Lyons Creek, TC=Tee Creek, BEC=Beaver Creek, UC= Usshers Creek.

Site	Ref creek avg (SD)	TC01	UC01	BEC02	LC01	LC03	LC08	LC12[a]	LC16	LC18	LC22	LC38
Zone	Reference	Ref	Ref	Ref	1- u/s	1	2	2	3	4	5	d/s Ref
Distance from headwaters (km)					*0.01*	*0.08*	*0.5*	*1*	*1.5*	*2*	*3.6*	*12*
No. Taxa	20 (4)	24	16[b]	18	14[b]	16	9	16	21	20	6[b]	14[b]
Total Abundance	16304 (10532)	6600	27503	14809	12731	32207	6212	12988	6876	3424	4403	9752
Naididae[c]	9922 (10156)	915	20929	7921	12091	29554	724	1568	249	353	1086	4667
Chironomidae	3652 (1633)	3712	1990	5255	274	663	603	6675	3333	1347	2292	3347
Amphipoda[d]	331 (507)	915	0	78.8	0	0	1448	101	1386	640	0	0
Ephemeroptera[e]	280 (153)	118	422	300	12.9	121	0.0	181	471	78.4	60.3	25.9
Trichoptera[f]	142 (126)	287.8	60	78.4	38.8	60.3	121	161	353	65.5	0	25.9
Trombidiformes[g]	12.9 (22)	38.8	0	0	12.9	60.3	0	261	117	39.2	60.3	52.2
Pisidiidae	367 (305)	38.8	422	640	12.9	844	844	141	0	25.9	0	1320
Ceratopogonidae	71 (44)	52.5	120.6	38.8	0	60.3	0	3780	209	12.9	844	26.3
Gastropoda[h]	150 (88)	65.1	241	144	12.9	422	422	60.3	78	235	0	0
Glossiphoniidae	60 (104)	0	181	0	26.3	60.3	60.3	0	12.9	26.3	0	0
Coenagrionidae	77 (16)	91.4	60.3	78.4	0	60.3	0	0	196	431	0	0
Asellidae	583 (1010)	0	1749	0	0	0	1809	0	0	0	0	52.2
Hydrodromidae	0 (0)	0	0	0	0	0	0	121	52.2	26.3	0	0

[a] value represents mean of 3 sets of core tube collections (QA/QC site)
[b] richness underestimated by 1-2 amphipod taxa
[c] includes subfamily Tubificinae
[d] sum of Hyalellidae and Gammaridae
[e] sum of Baetidae, Caenidae, Ephemeridae and Heptageniidae
[f] sum of Hydroptilidae, Leptoceridae, Phryganeidae, Polycentropodidae and Dipseudopsidae
[g] sum of Arrenuridae, Hydrodromidae, Limnesiidae, Oxidae, Pionidae, and Unionicolidae
[h] sum of Ancylidae, Hydrobiidae, Physidae, Valvatidae, and Planorbidae

Table 9. Mean percent survival, growth (mg dw per individual) and reproduction in bioassays conducted on 2015 Lyons Creek East and neighbouring reference creek sediments. Numerical guidelines for each endpoint based on 66 Great Lakes reference sites are provided; test site potential toxicity and toxicity are indicated in blue and red, respectively. LC = Lyons Creek, TC=Tee Creek, BEC=Beaver Creek.

Organism	C. riparius		H. azteca		Hexagenia spp.		T. tubifex			
Endpoint	% surv	growth	% surv	growth	% surv	growth	% surv	no. cocoons/ adult	% cocoons hatched	no. young/ adult
GL Ref[a]	*89.8*	*0.36*	*87.9*	*0.52*	*98.9*	*4.18*	*99.9*	*10.3*	*56.5*	*22.1*
LC01	86.7	0.33	81.3	0.24	98	6.08	100	9.0	50.2	20.6
LC03	**73.3**	0.29	**60.0**	**0.17**	**0**	**0.00**	100	**2.2**	90.8	**1.1**
LC08	98.7	0.36	**61.3**	**0.14**	**84**	1.26	100	**5.2**	37.9	11.0
LC12	93.3	0.45	88.3	0.26	96	2.21	100	**7.8**	40.4	18.2
LC16	96.0	0.35	**28.0**	**0.14**	96	4.86	100	10.5	60.7	21.3
LC18	94.7	0.34	89.3	0.30	98	6.99	100	10.3	52.2	26.0
LC22	96.0	0.33	72.0	0.29	96	6.14	100	10.5	54.9	32.9
LC38	92.0	0.31	96.0	0.43	98	3.99	100	**6.3**	**24.1**	20.6
TC01	90.7	0.33	89.3	0.25	100	4.45	100	11.7	61.9	24.7
BEC02	86.7	0.28	88.3	0.33	100	6.47	100	8.8	**31.5**	**6.1**
Non-toxic	≥75.8	0.53 - 0.21	≥69.2	0.83 - 0.21	≥95.1	7.87 - 0.50	≥98.4	12.8 – 7.9	78.4 – 34.7	38.0 - 6.4
Pot. Toxic	75.7- 68.6	0.20 - 0.12	69.1 - 59.7	0.20 - 0.05	95.0 - 93.0	0.49 - 0.00	98.3 - 97.5	7.8 - 6.6	34.6 – 23.7	6.3- 0.1
Toxic	<68.6	<0.12	<59.7	<0.05	<93.0	negative	<97.5	<6.6	<23.7	0

[a] Great Lakes reference sites (n=66, ECCC unpublished data)

Table 10. Summary of status and trends for sediment contamination, benthic invertebrate communities and toxicity for Lyons Creek East.

Indicator	Status of Lyons Creek East sites in 2015 Relative to local reference sites	Trend from 2002 to 2015
Sediment Contaminant Levels		
Total PCB congeners	higher	stable except LC03
Arsenic	higher	stable or decreasing
Cadmium	similar	stable or decreasing
Chromium	higher	stable or decreasing except LC03
Copper	higher	stable
Lead	similar or higher	stable or decreasing
Mercury	similar except LC03	stable except LC03
Nickel	similar except LC03	stable
Zinc	higher	stable or decreasing
Total PAHs	similar except LC03	stable except LC03
Total petroleum hydrocarbons	higher	stable or decreasing except LC03
Invertebrate Total PCB Congener Levels		
Amphipods	higher	variable
Benthic Community		
Whole community NMS	similar except LC08	stable from 2010
Total benthos	similar or lower	mostly stable
Taxon richness	similar or lower	variable
Evenness	variable	stable or decreasing
Diversity	variable	stable or decreasing
Naididae	similar or lower except LC03	variable
Chironomidae	similar or lower	decreasing
Amphipoda	similar or higher	stable
Ephemeroptera	similar or lower	variable
Trichoptera	similar or lower	mostly decreasing
Sediment Toxicity[a]		
Integrated endpoints NMS[b]	toxicity in upper creek	stable since 2010
H. azteca survival	similar or lower	stable except LC16
H. azteca growth	lower	stable or decreasing
C. riparius survival	similar	stable or increasing
C. riparius growth	similar	stable or increasing
Hexagenia spp. survival	similar or lower	stable or increasing
Hexagenia spp. growth	similar or lower	stable or increasing
T. tubifex survival	similar	stable
T. tubifex cocoon production	similar or lower	stable mostly
T. tubifex cocoon hatching	similar or lower	increasing
T. tubifex young production	similar or lower	stable or increasing

[a] toxicity relative to Great Lakes reference sites; [b] nonmetric multidimensional scaling

FIGURES

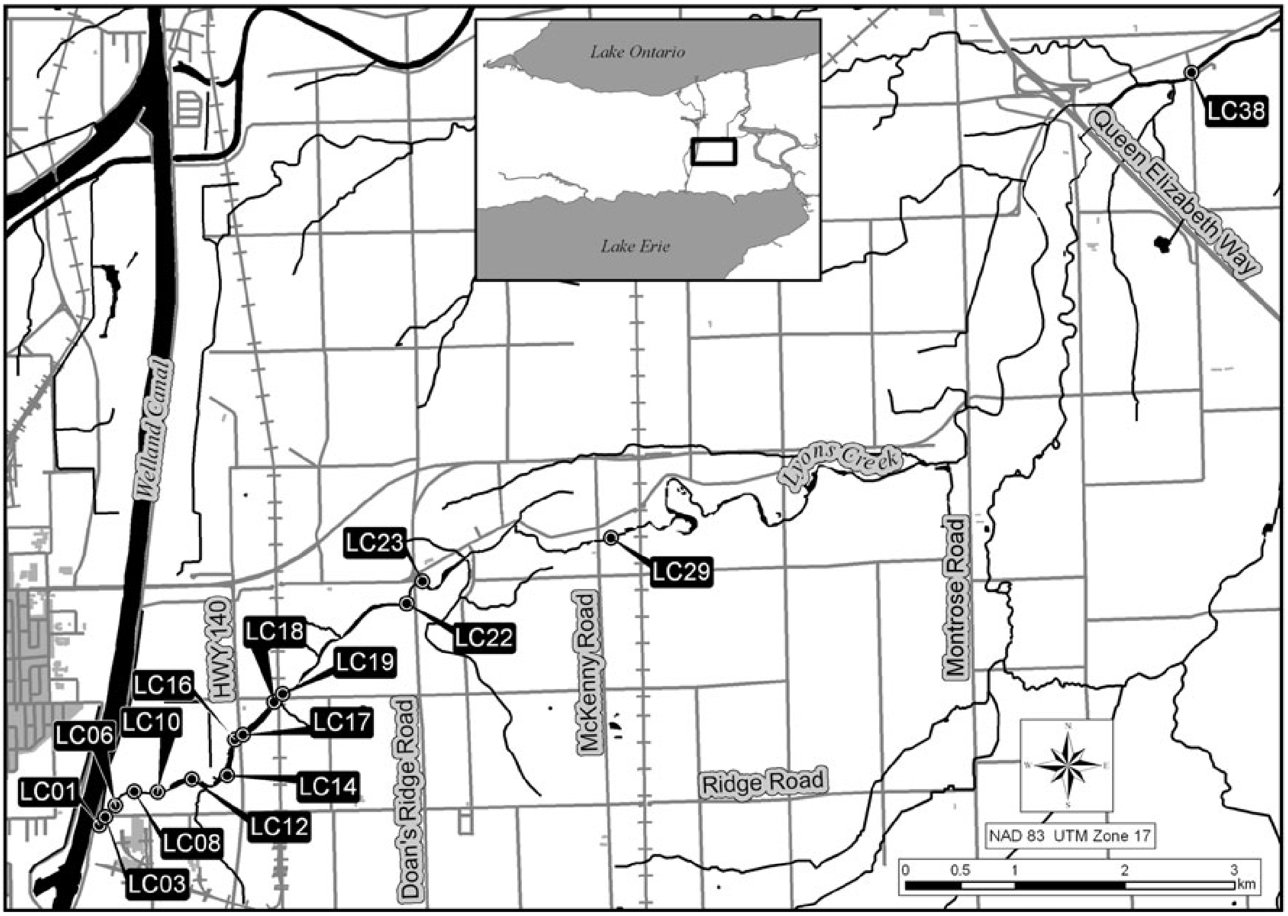

Figure 1A. Lyons Creek East sampling site locations 2002-2015. Sites sampled in 2015 (n=8) included LC01, LC03, LC08, LC12, LC16, LC18, LC22 and LC38.

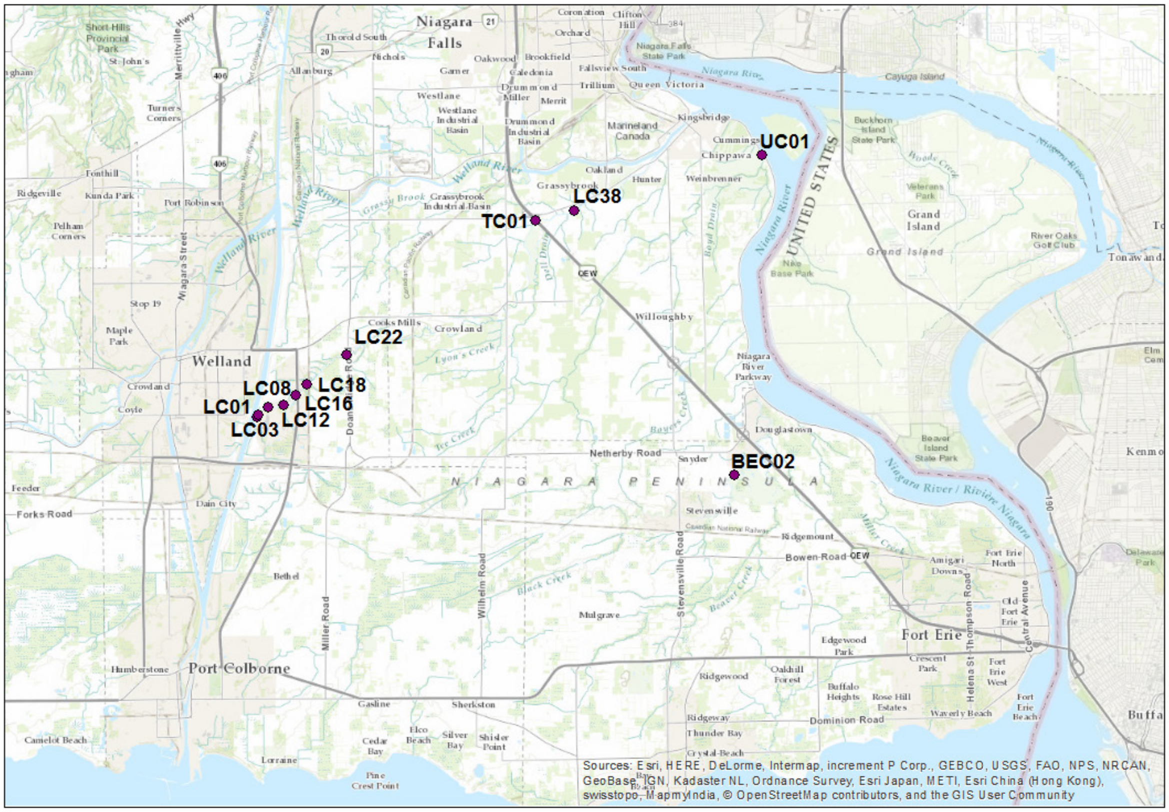

Figure 1B. Location of 2015 Lyons Creek East and neighbouring reference creek sites. LC= Lyons Creek East, TC = Tee Creek, UC = Usshers Creek, and BEC = Beaver Creek.

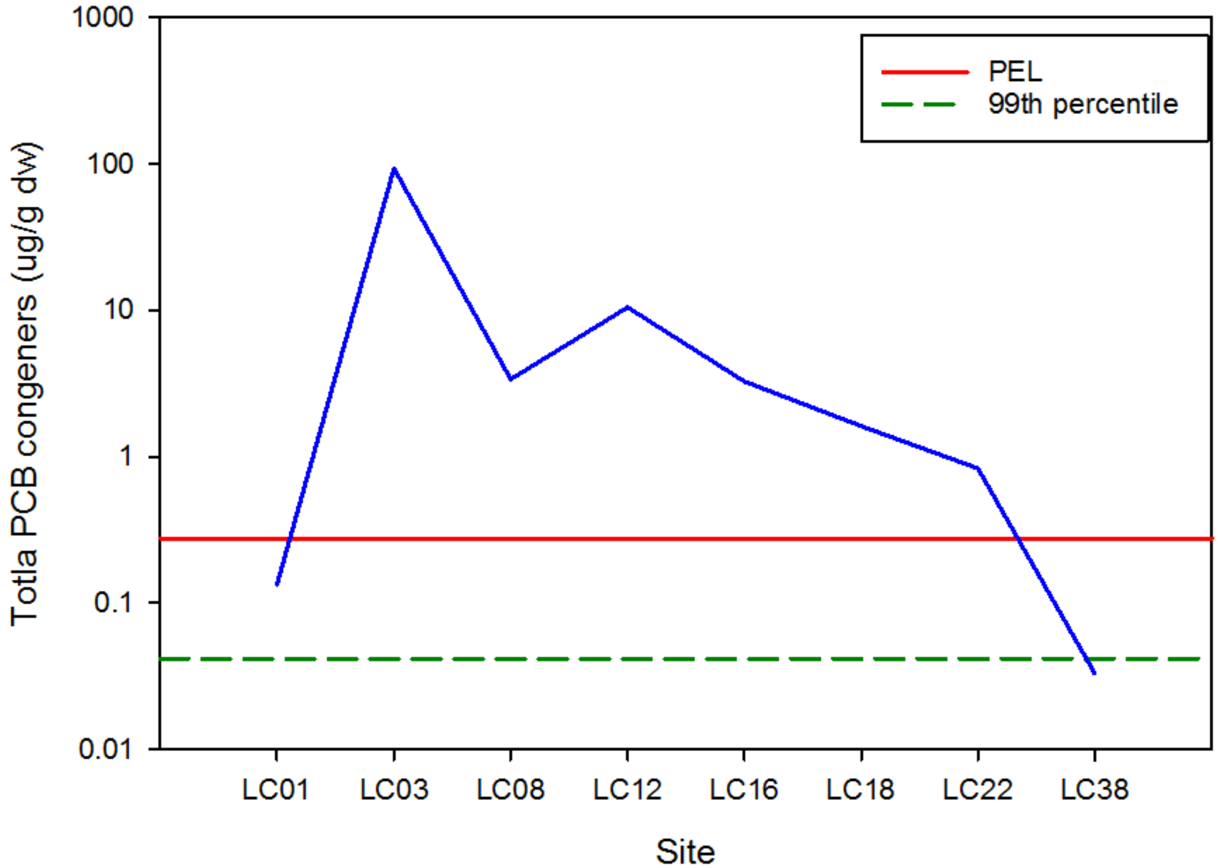

Figure 2. Concentrations of sediment total PCB congeners in Lyons Creek East from 2015. Sites are in order from upstream to downstream. The solid red line is the Probable Effect Level (PEL; 0.277 µg/g) and the green dashed line is the 99^{th} percentile concentration for neighbouring reference creeks (n=3; 0.042 µg/g).

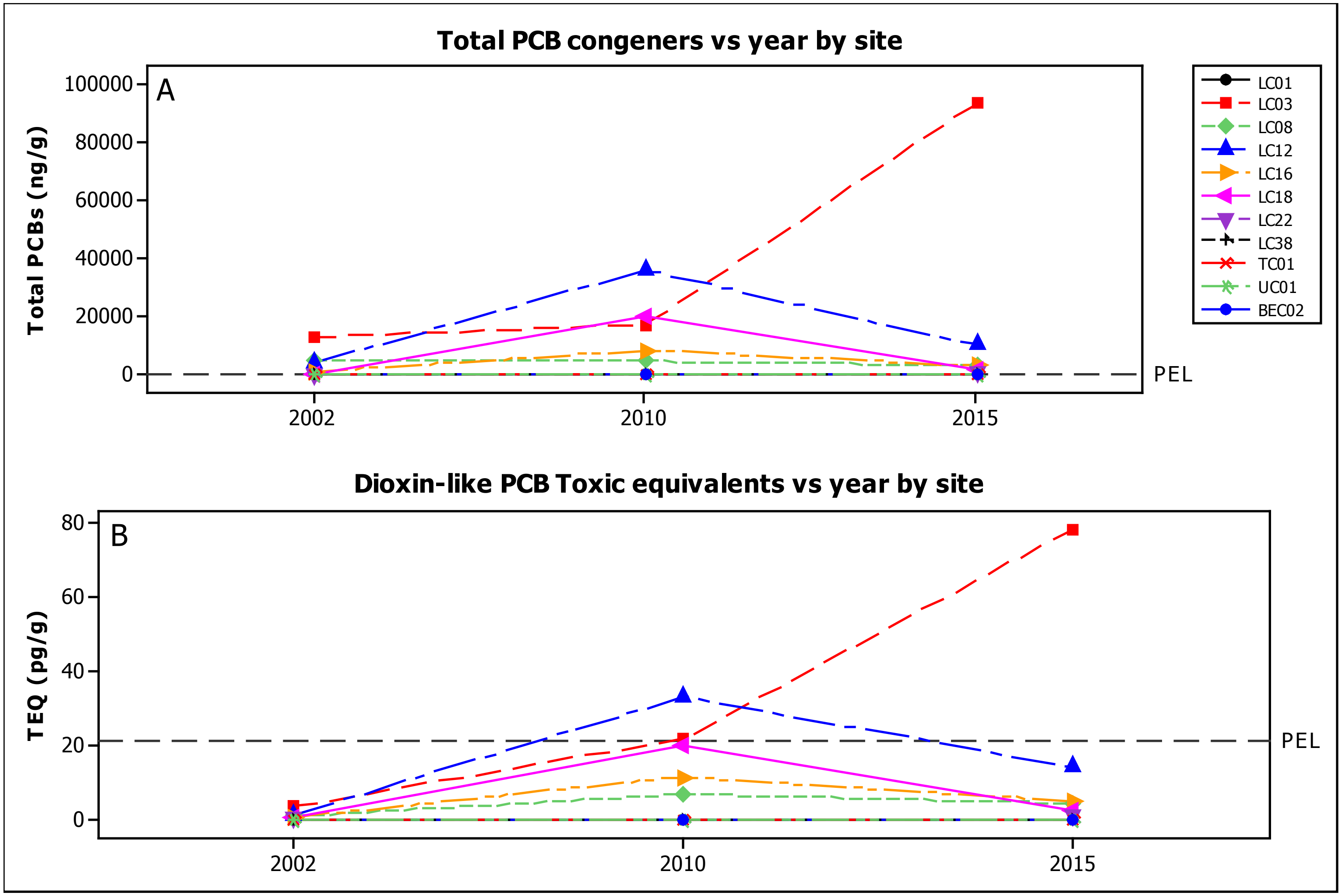

Figure 3. Trends in sediment concentrations of PCBs expressed in (A) total congeners, and (B) toxic equivalents (TEQ; mid-point scenario) from co-located Lyons Creek East and reference creek sites sampled 2002-2015. The probable effect level (PEL) for PCBs (277 µg/kg) and for dioxins and furans (21.5 pg TEQ/g) (CCME 2001a) are indicated. LC = Lyons Creek, TC= Tee Creek, UC=Usshers Creek, BEC=Beaver Creek.

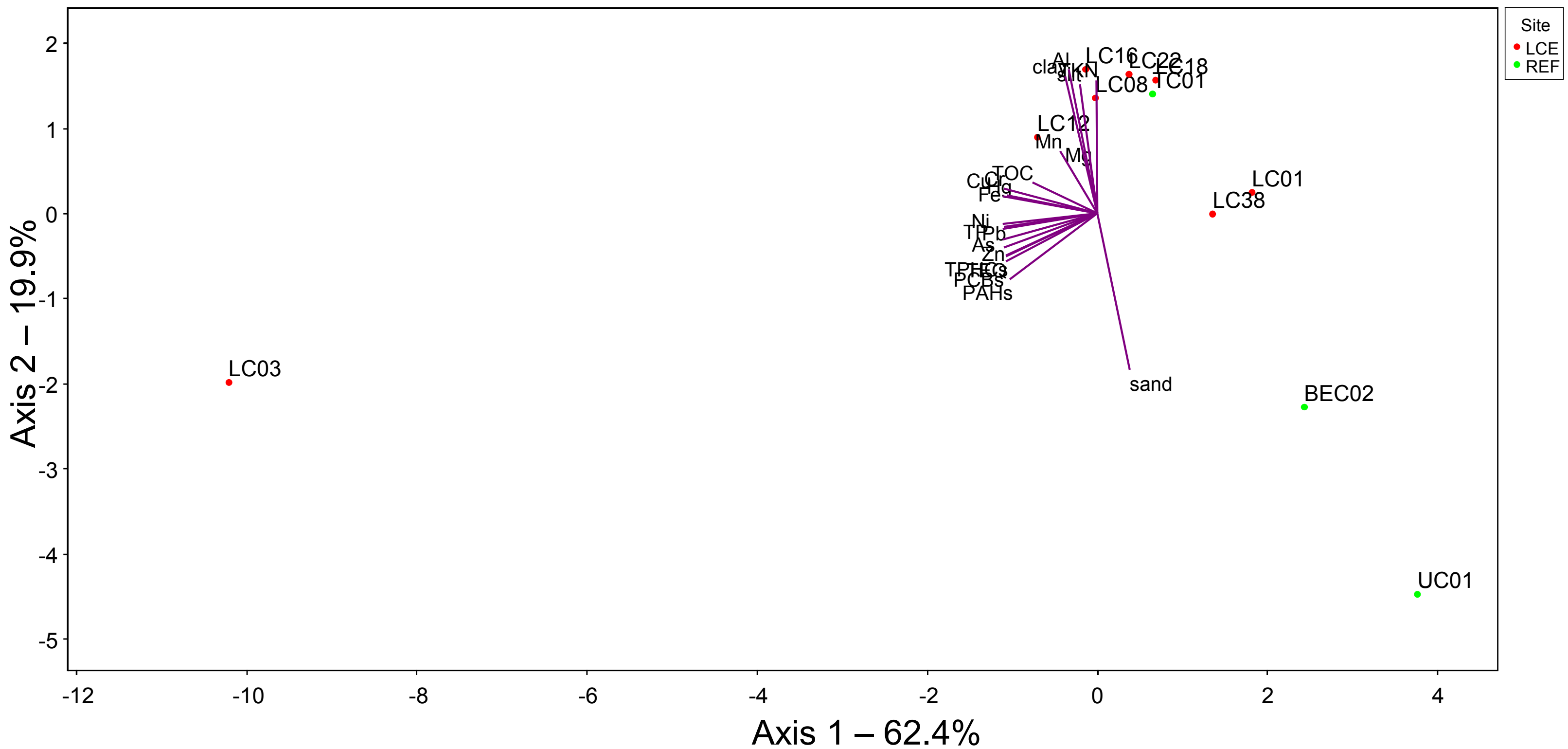

Figure 4A. Principal components analysis of 2015 Lyons Creek East site environmental data (21 sediment variables) showing site scores variable loadings. The percent variation explained by each axis is provided.

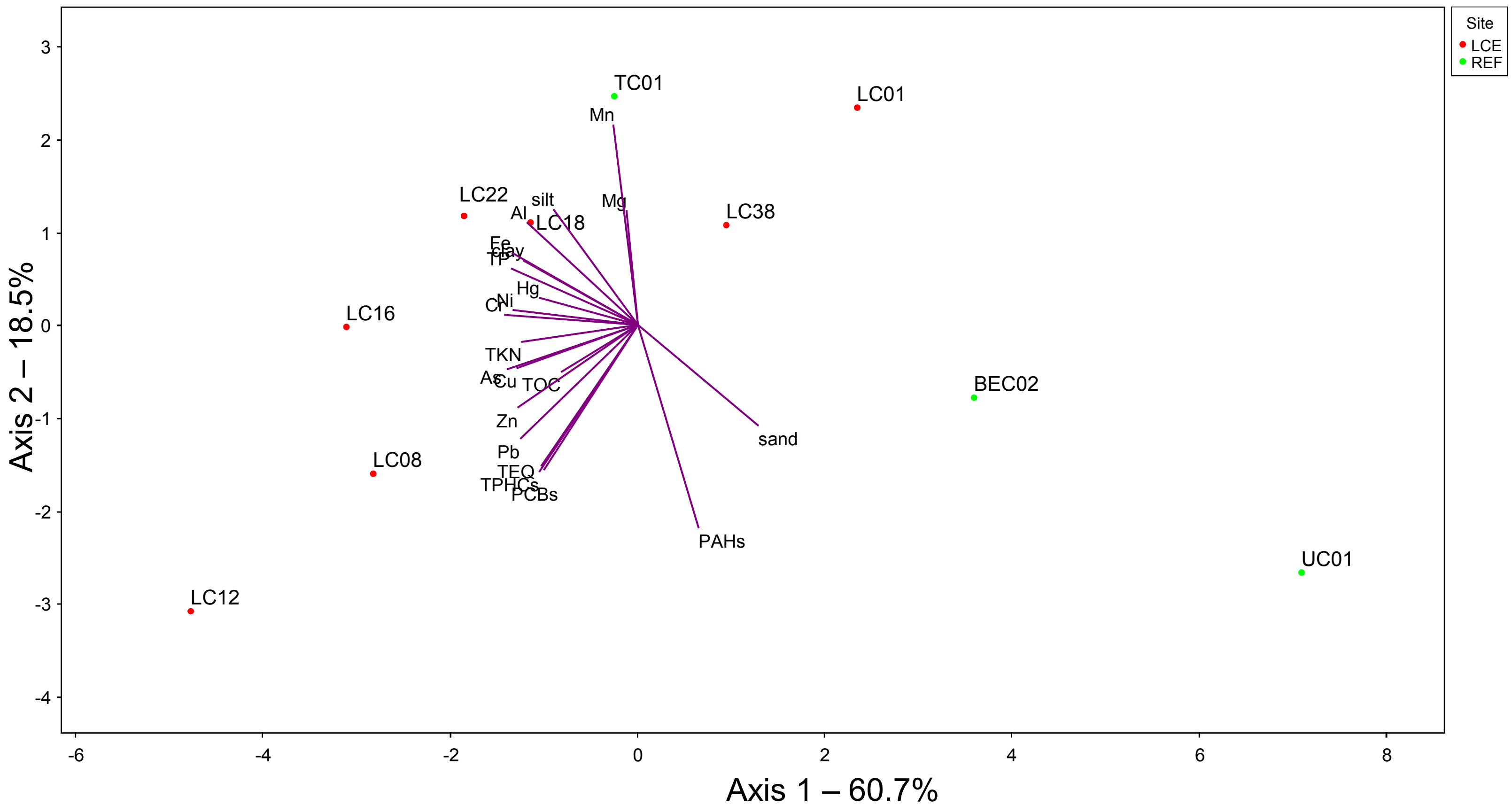

Figure 4B. Principal components analysis of 2015 Lyons Creek East site environmental data (21 sediment variables) without site LC03, showing site scores variable loadings. The percent variation explained by each axis is provided.

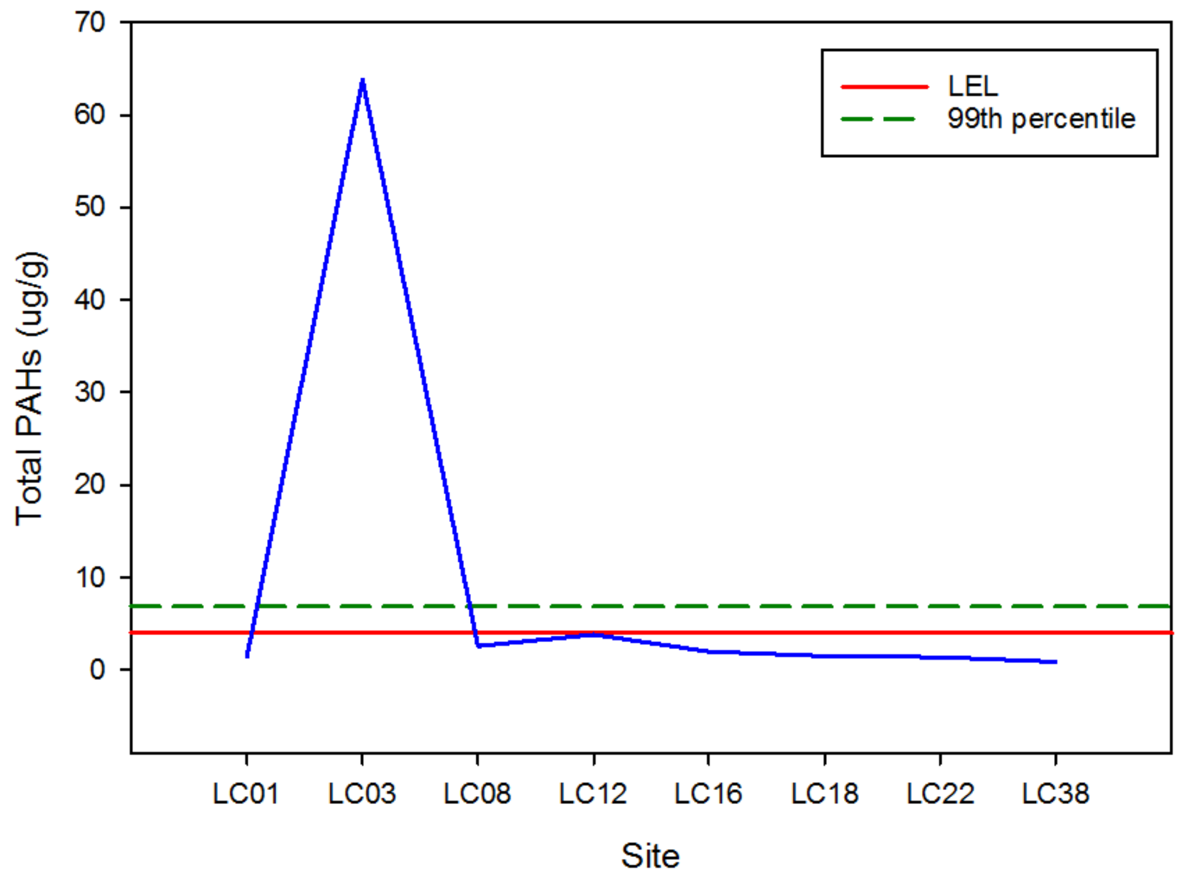

Figure 5. Concentrations of sediment total PAHs (sum of 18 parent compounds) in Lyons Creek East from 2015. Sites are in order from upstream to downstream. The solid red line is the lowest effect level for total PAHs (4 µg/g; Fletcher et al. 2008) and the green dashed line is the 99th percentile concentration for neighbouring reference creeks (n=3; 6.87 µg/g).

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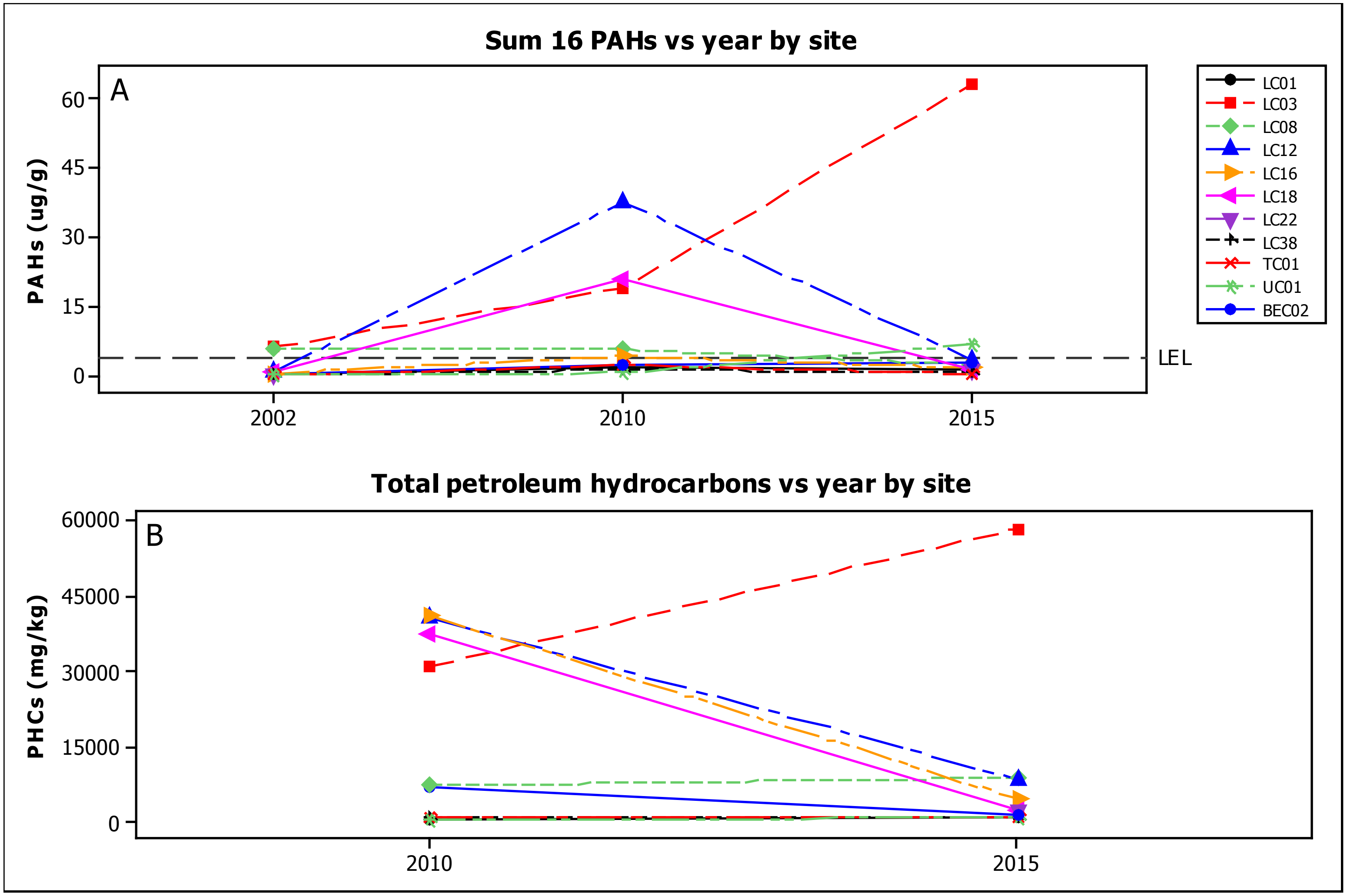


Figure 6. Trends in concentrations of sediment (A) PAHs (sum of 16 parent compounds) from 2002-2015, and (B) total petroleum hydrocarbons from 2010-2015, from co-located Lyons Creek East and reference creek sites. The lowest effect level (LEL) for total PAHs (4 µg/g; Fletcher et al. 2008) is indicated. LC = Lyons Creek, TC= Tee Creek, UC=Usshers Creek, BEC=Beaver Creek.

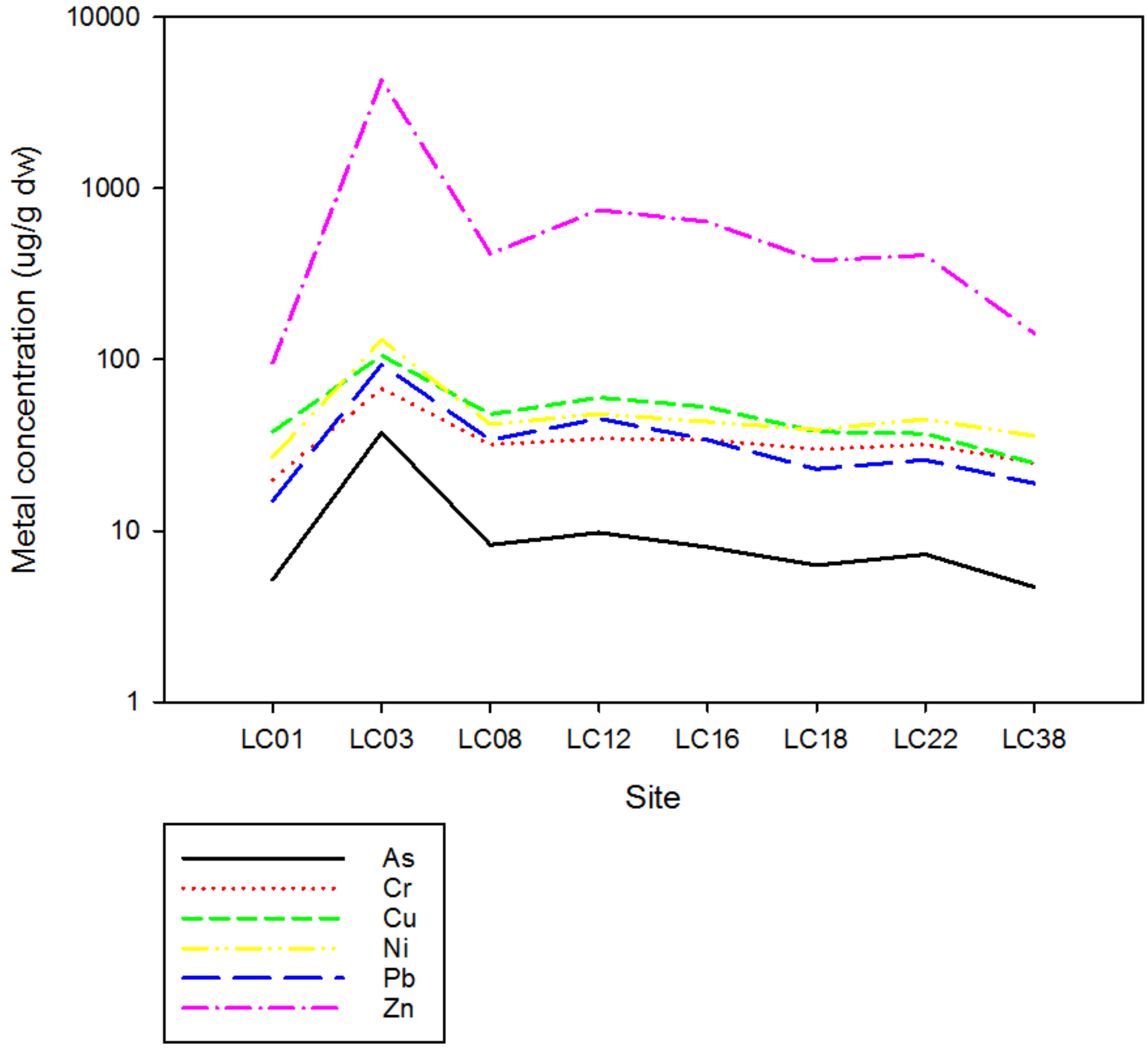


Figure 7. Concentrations of 6 metals in Lyons Creek East sediment from 2015. Sites are in order from upstream to downstream.

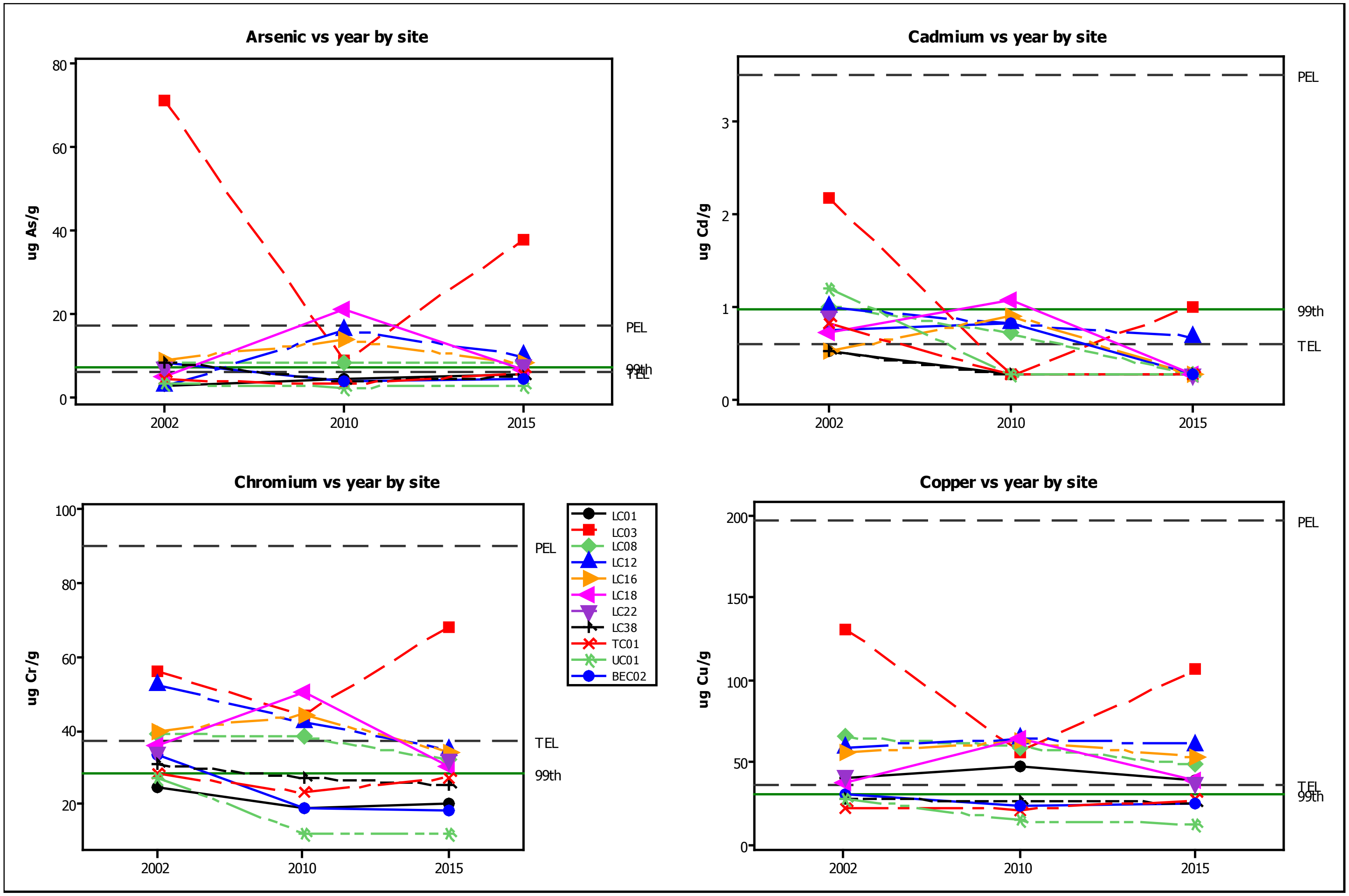


Figure 8A. Trends in concentrations of extractable arsenic, cadmium, chromium and copper in sediment from co-located Lyons Creek East and reference creek sites sampled 2002-2015. The threshold/probable effect levels (TEL/PEL) (CCME 2001a) or lowest/severe effect levels (LEL/SEL) (Fletcher et al. 2008) are indicated. The solid green line is the 99[th] percentile for Lake Erie reference sites sampled 2010-2014 (n=19). LC = Lyons Creek, TC= Tee Creek, UC=Usshers Creek, BEC=Beaver Creek.

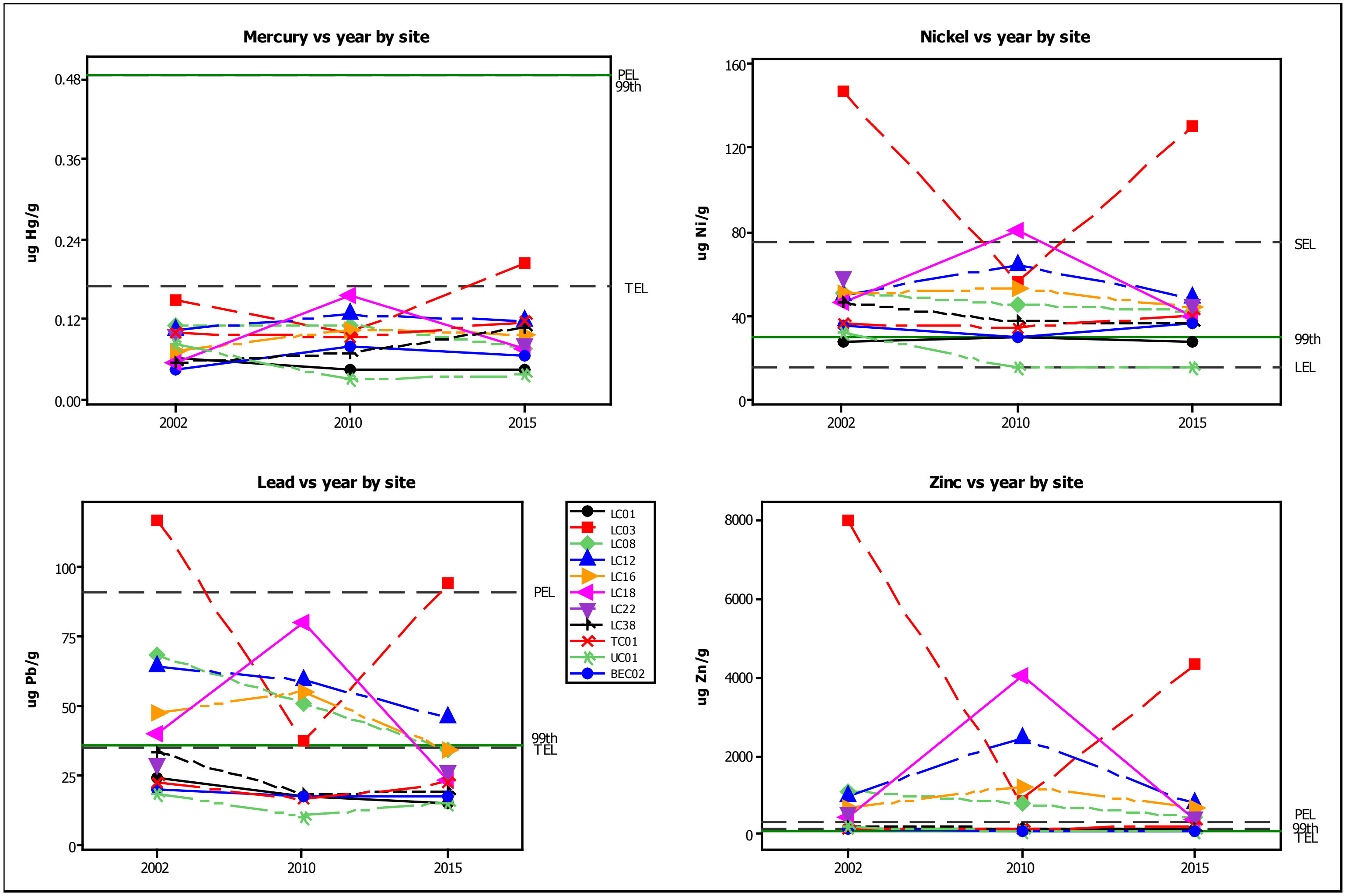


Figure 8B. Trends in concentrations of extractable mercury, nickel, lead and zinc in sediment from co-located Lyons Creek East and reference creek sites sampled 2002-2015. The threshold/probable effect level (TEL/PEL) (CCME 2001a) or lowest/severe effect levels (LEL/SEL) (Fletcher et al. 2008) are indicated. The solid green line is the 99th percentile for Lake Erie reference sites sampled 2010-2014 (n=19). LC = Lyons Creek, TC= Tee Creek, UC=Usshers Creek, BEC=Beaver Creek.

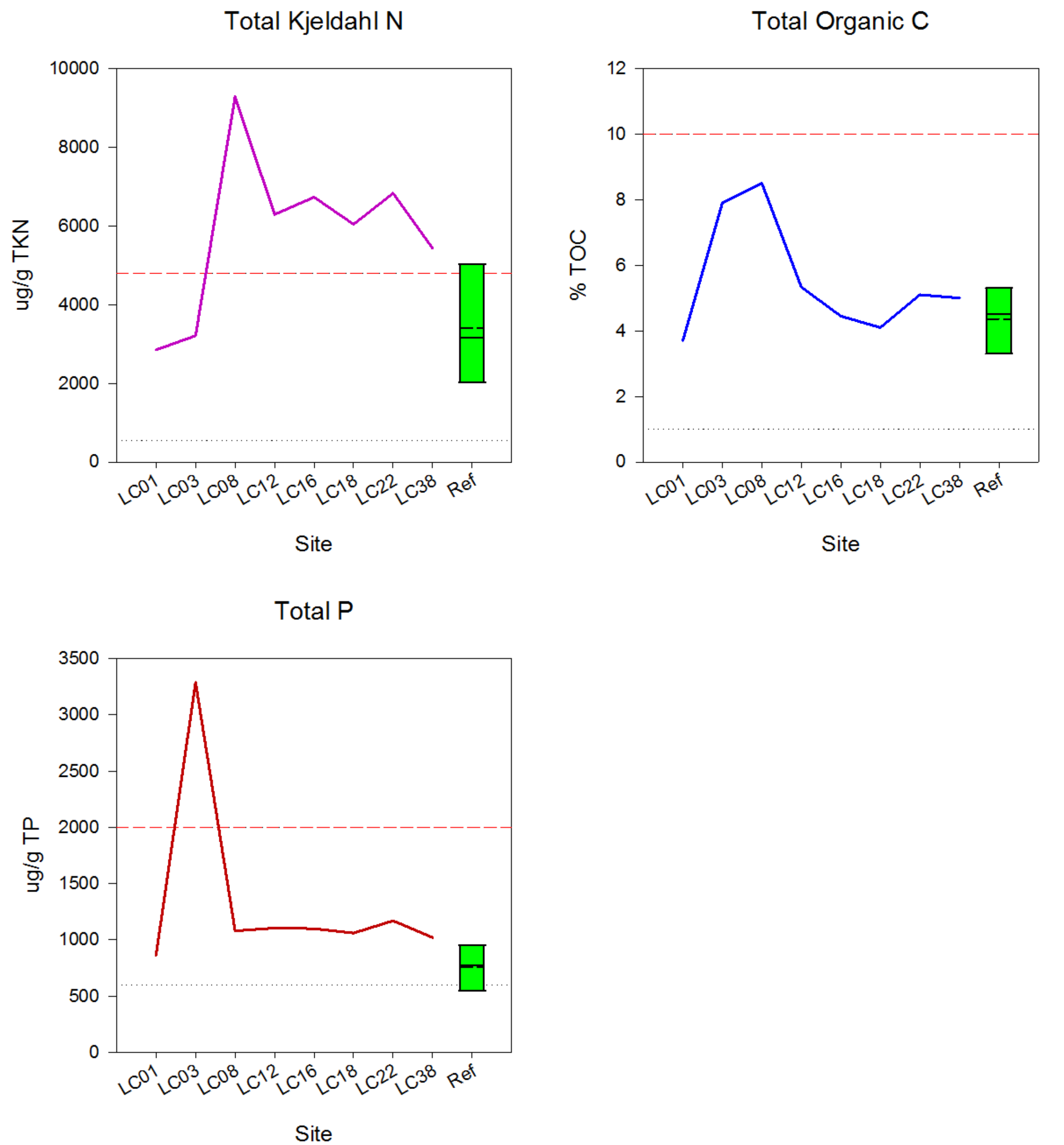


Figure 9. Sediment nutrient concentrations in Lyons Creek East from 2015. The red dashed line represents the severe effect level and the dotted line is the lowest effect level (Fletcher et al. 2008). The green box plot represents the interquartile ranges, mean (dashed line) and median (solid line) observed for the three neighbouring reference creeks (Tee, Usshers, and Beaver).

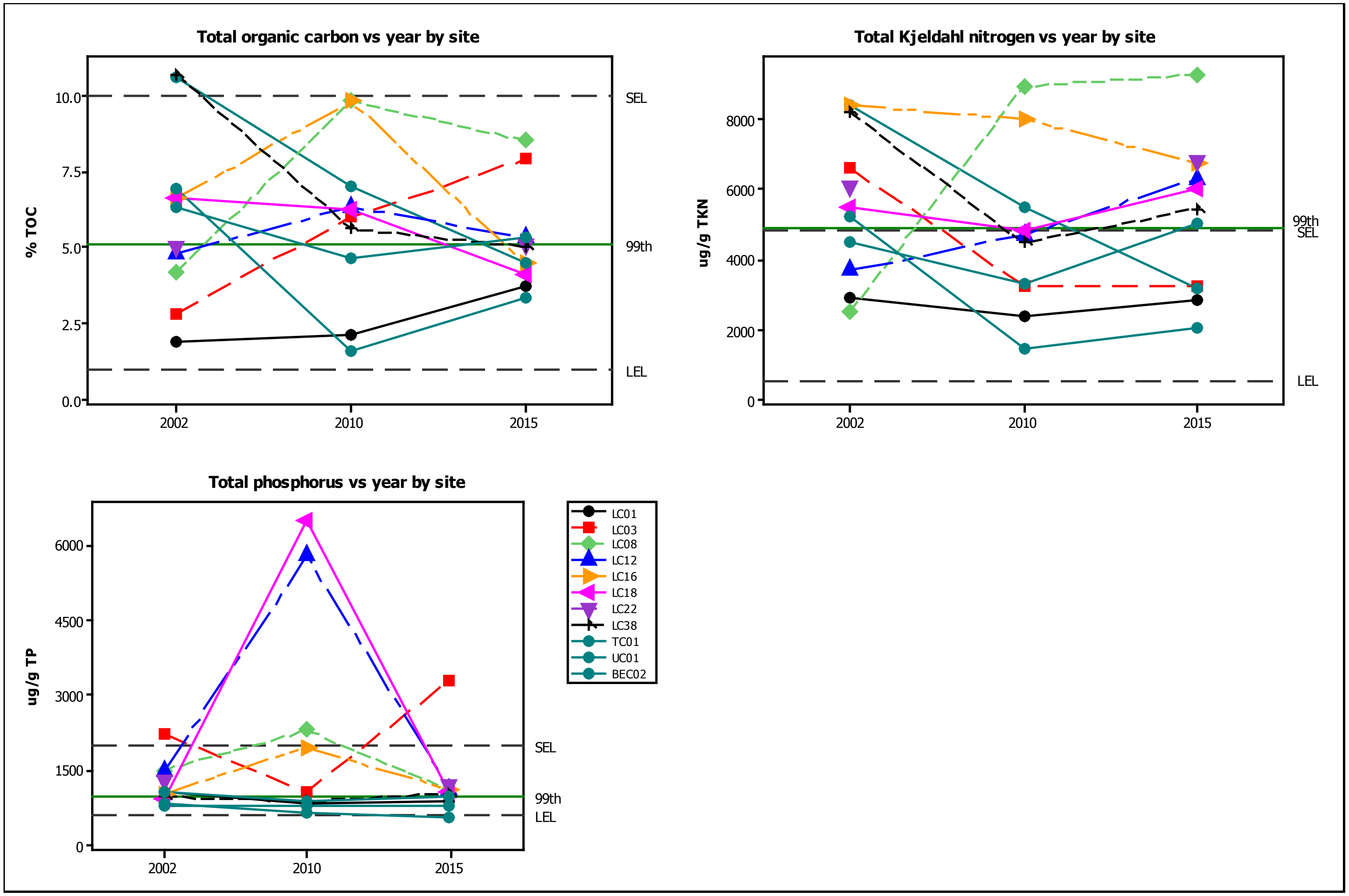


Figure 10. Trends in sediment total organic carbon (%), total Kjeldahl nitrogen, and total phosphorus concentrations (µg/g dw) for co-located Lyons Creek East and reference creek sites sampled 2002-2015. The lowest effect level (LEL) and the severe effect level (SEL) are indicated. The solid green line is the 99th percentile for Lake Erie reference sites sampled 2010-2014 (n=19). LC = Lyons Creek, TC= Tee Creek, UC=Usshers Creek, BEC=Beaver Creek.

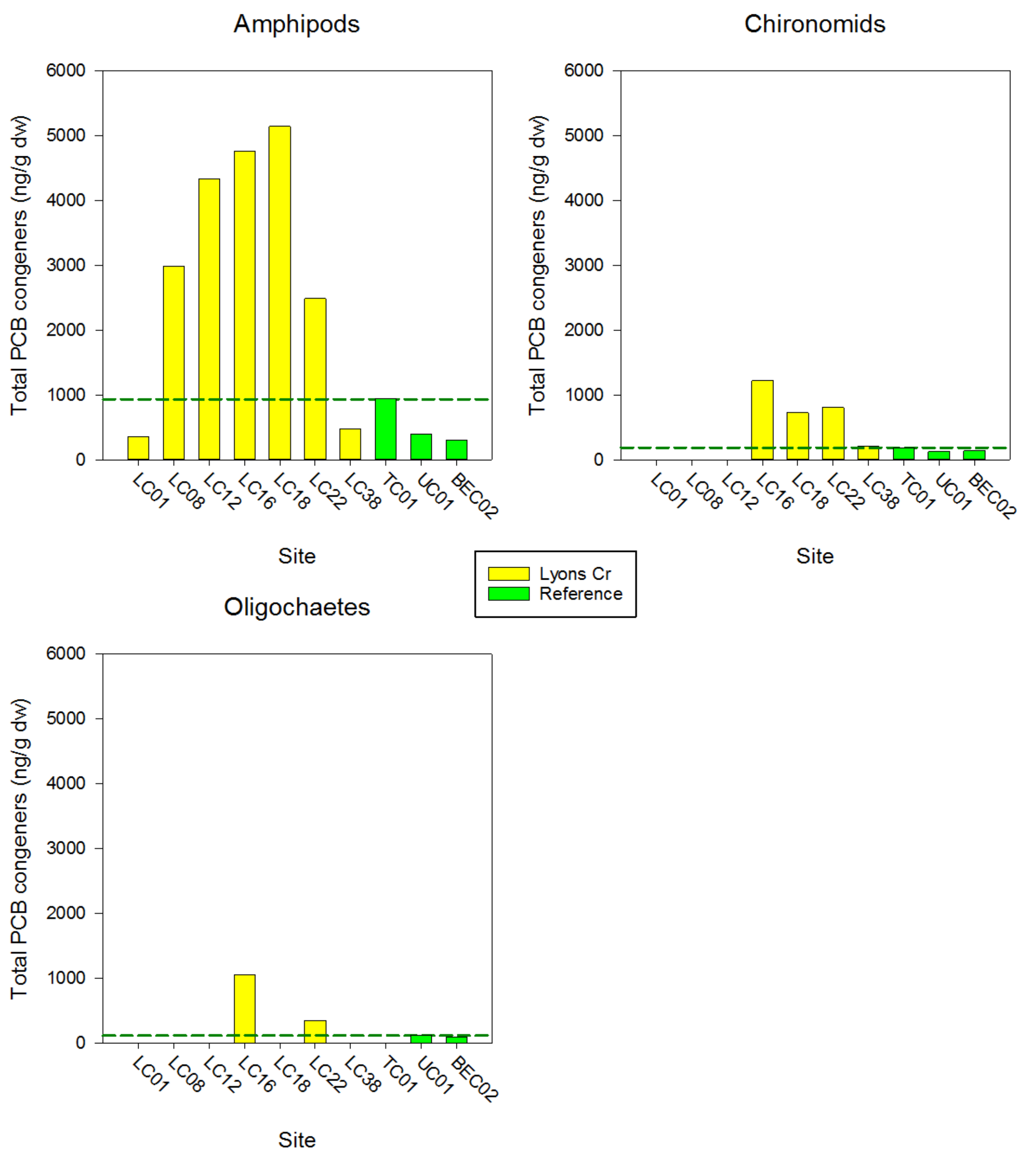


Figure 11A. Concentrations of total PCB congeners (ng/g dw) for individual groups of native benthic invertebrates collected from Lyons Creek East (yellow bars) and neighbouring reference creeks (green bars) in 2015. The 99th percentile for the neighbouring reference site concentrations for total PCBs is indicated by the dashed line in each subfigure. TC= Tee Creek, UC=Usshers Creek, BEC=Beaver Creek.

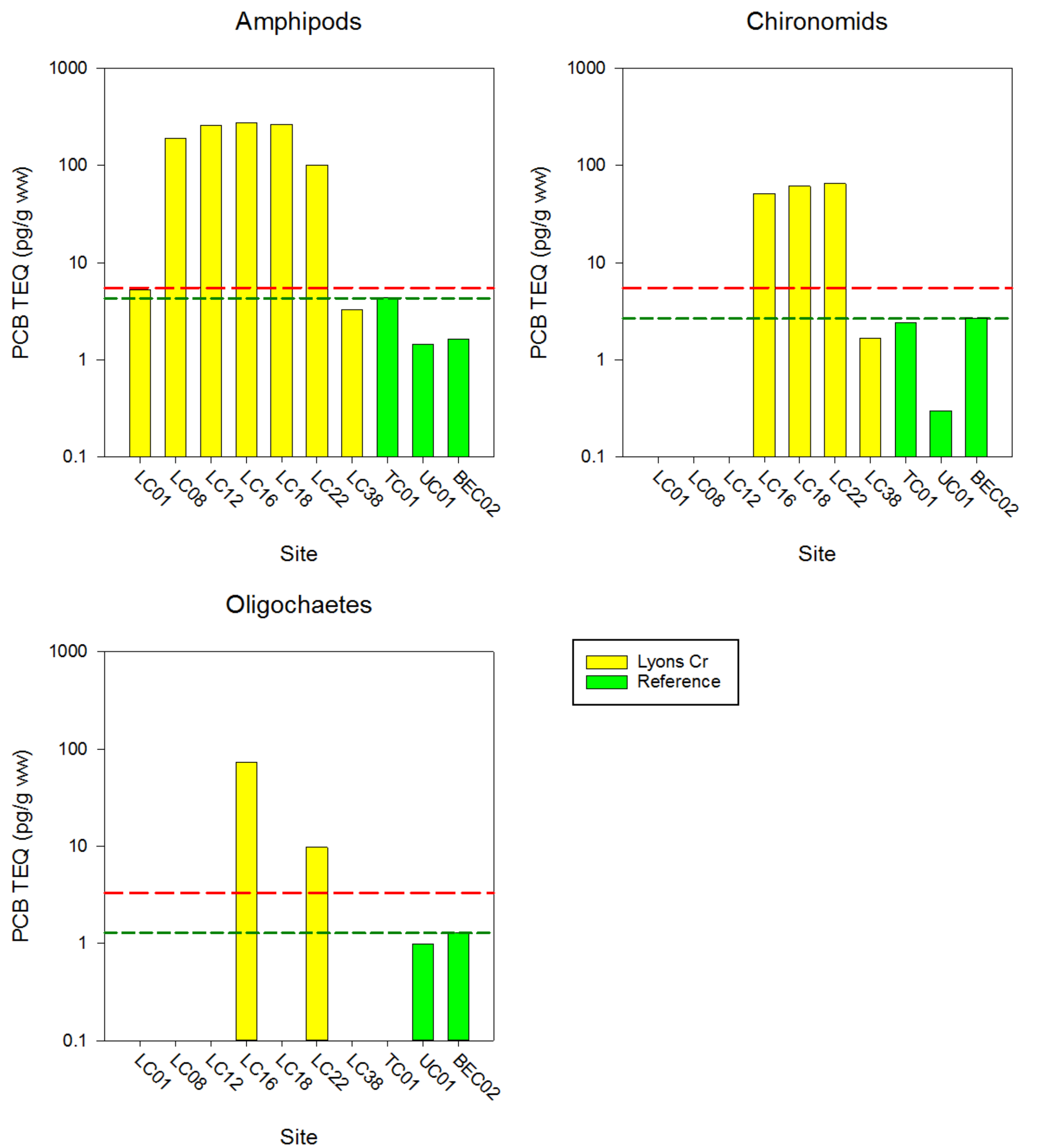


Figure 11B. Concentrations of PCB toxic equivalents (pg/g ww), for individual groups of native benthic invertebrates collected from Lyons Creek East (yellow bars) and neighbouring reference creeks (green bars) in 2015. The 99th percentile for the neighbouring reference site concentrations for total PCBs (green) and a reference concentration for an anseriforme (5.5 pg TEQ/g ww) (red) are indicated by the dashed lines in each subfigure. TC= Tee Creek, UC=Usshers Creek, BEC=Beaver Creek.

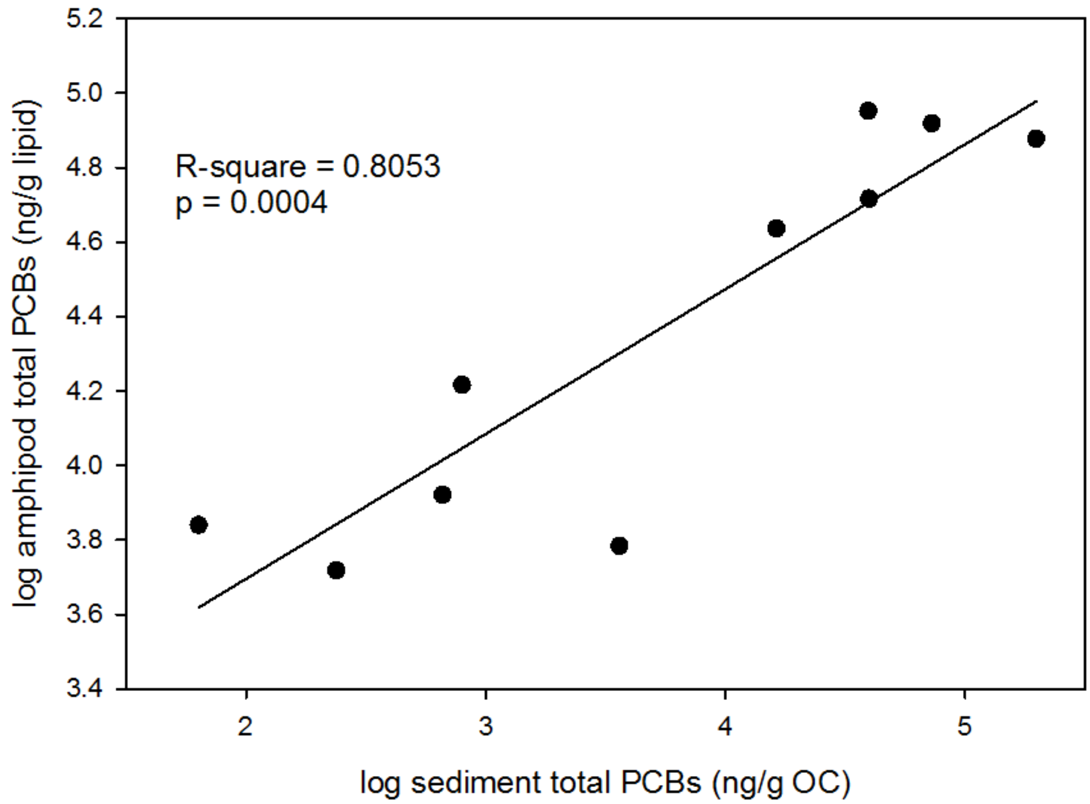


Figure 12. Relationship between logged total PCB congeners in amphipods (normalized to % lipids) and sediment (normalized to % organic carbon) for 2015 samples.

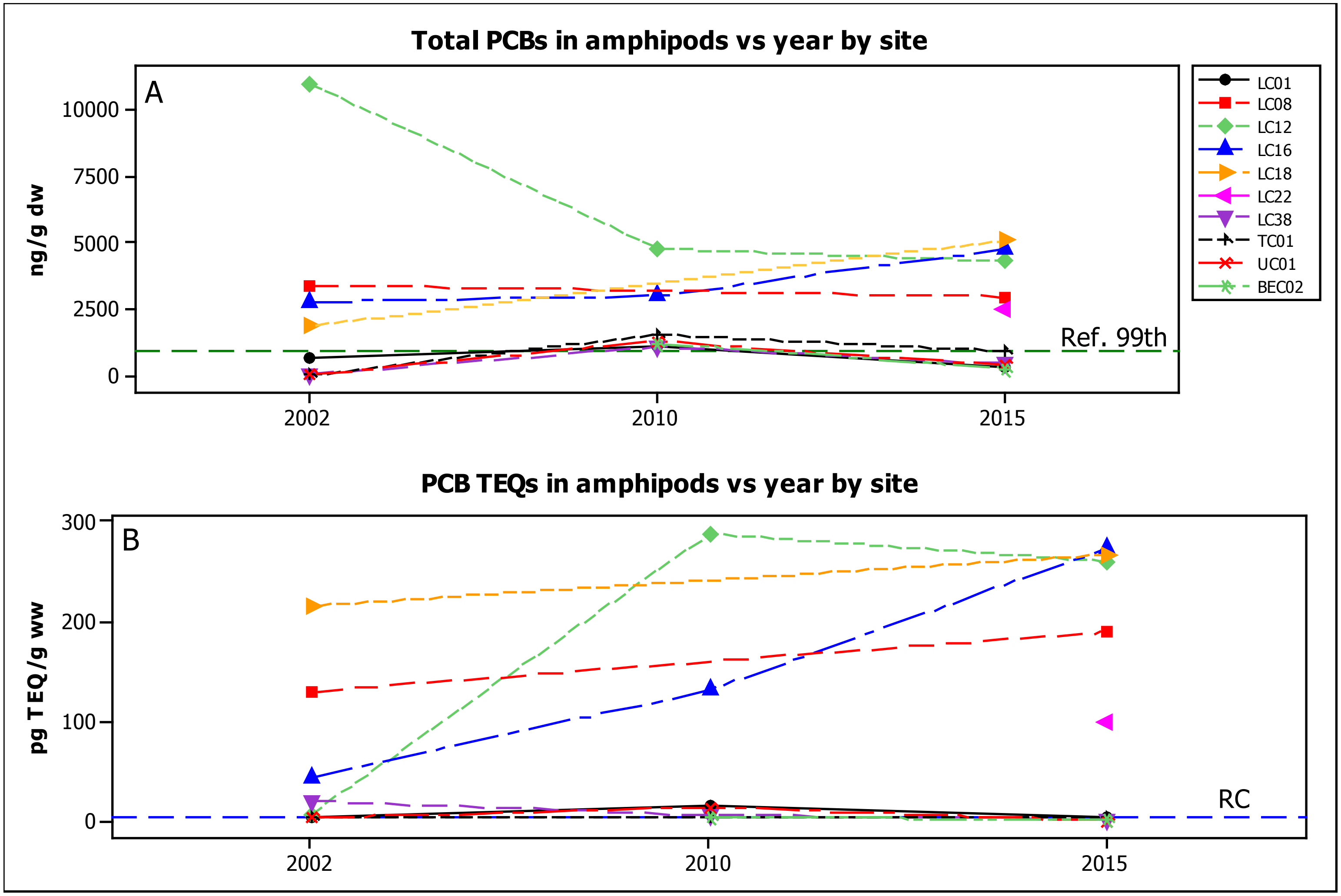


Figure 13. Trends in amphipod tissue PCB concentrations expressed in (A) total congeners, and (B) toxic equivalents (TEQ; mid-point scenario) from co-located Lyons Creek East and reference creek sites sampled 2002-2015. The 99th percentile for the 2015 neighbouring reference site concentrations for total PCBs (934 ng/g) and a reference concentration (RC) for an anseriforme (5.5 pg TEQ/g ww) are indicated. LC= Lyons Creek, TC= Tee Creek, UC=Usshers Creek, BEC=Beaver Creek.

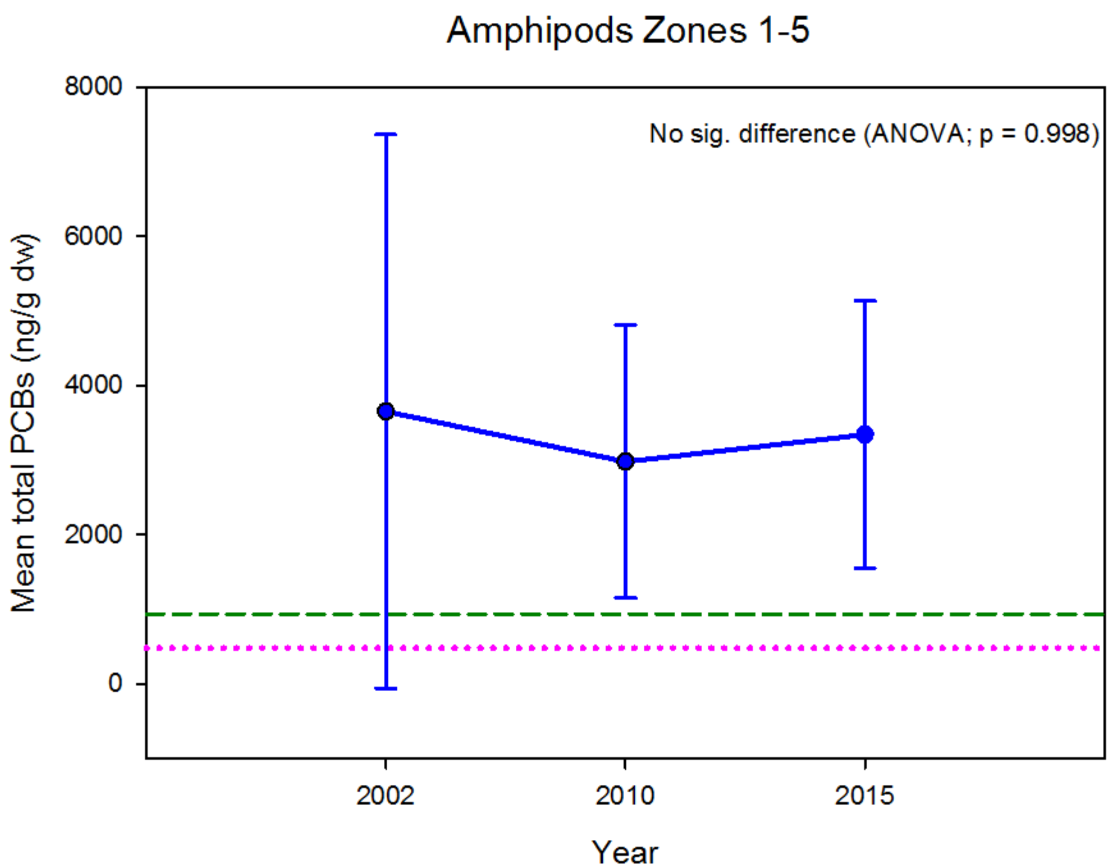
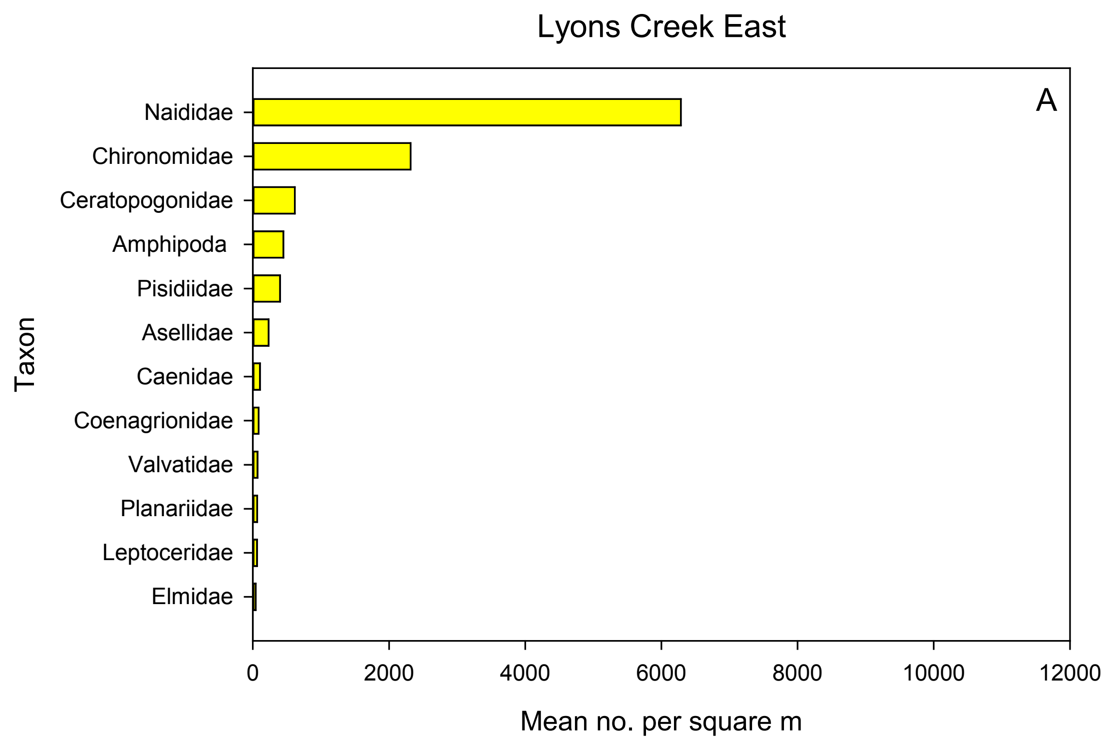


Figure 14. Concentrations (mean ± standard deviation) of total PCBs in amphipod tissue collected from zones 1 to 5 from 2002 to 2015 (n=3-6 sampling points). The dashed green line is the 99th percentile for PCBs in the 3 neighbouring reference creeks sampled in 2015 (934 ng/g) and the dotted line is the concentration of PCBs from amphipods at the downstream site LC38 (479 ng/g).



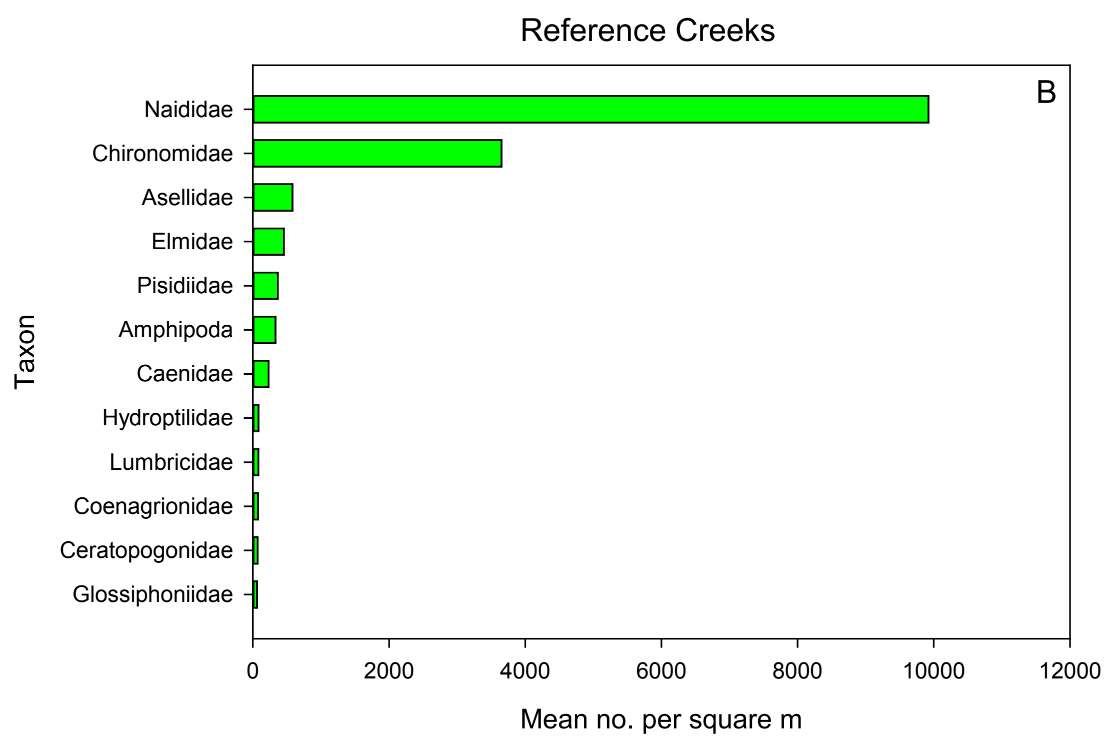


Figure 15. Mean abundance of predominant 12 macroinvertebrate families in samples collected in 2015 from (A) Lyons Creek East, and (B) neighbouring reference creeks (Tee, Usshers, and Beaver).

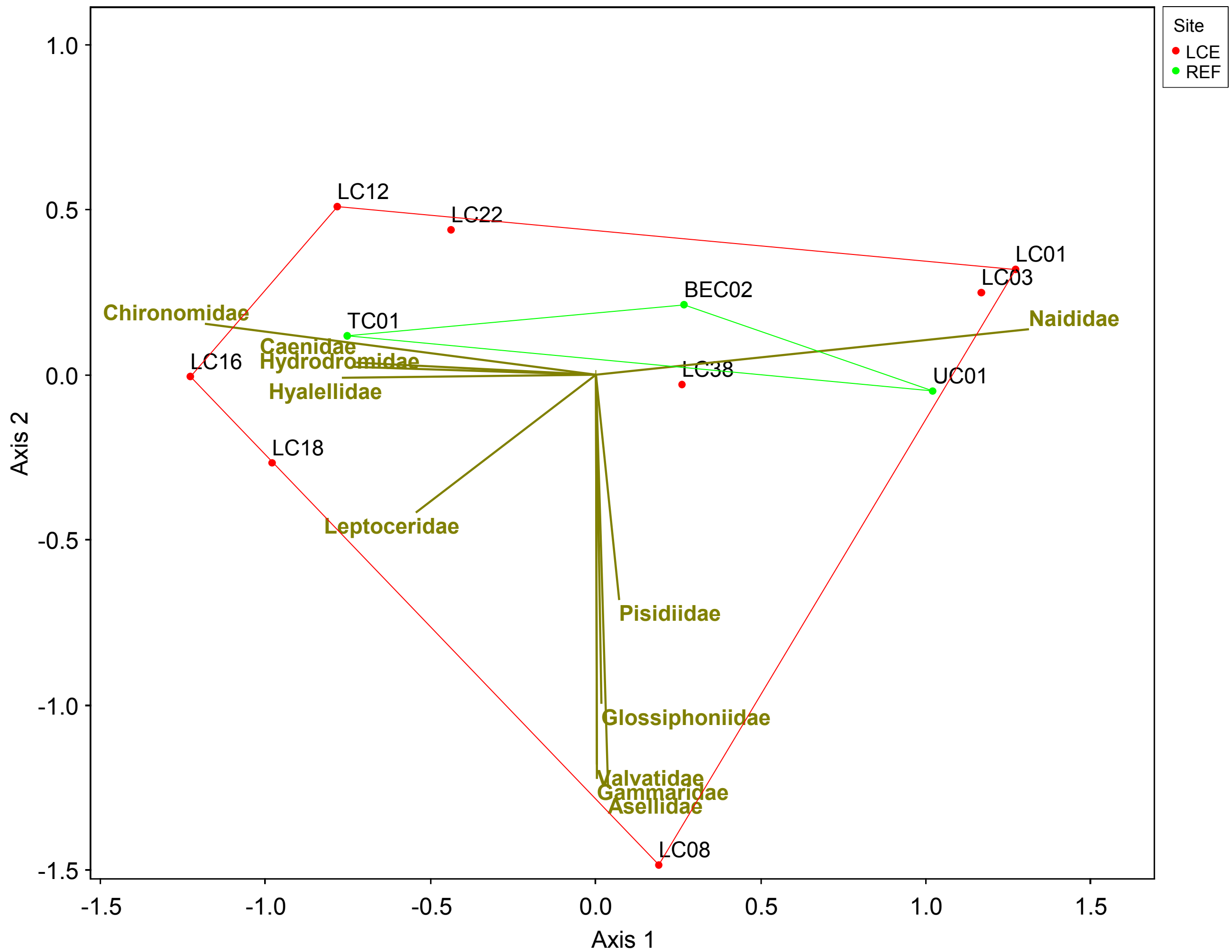


Figure 16A. Two-dimensional nonmetric multidimensional scaling of 2015 Lyons Creek East and reference creek benthic community composition (family level). Final stress = 4.54 for a 2-dimensional solution. Families with combined r^2 values of ≥ 0.45 are shown as vectors. Sample scores for Lyons Creek East (red) and neighbouring reference creeks (green) are enclosed by polygons to show group separation. LC= Lyons Creek, TC= Tee Creek, UC=Usshers Creek, BEC=Beaver Creek.

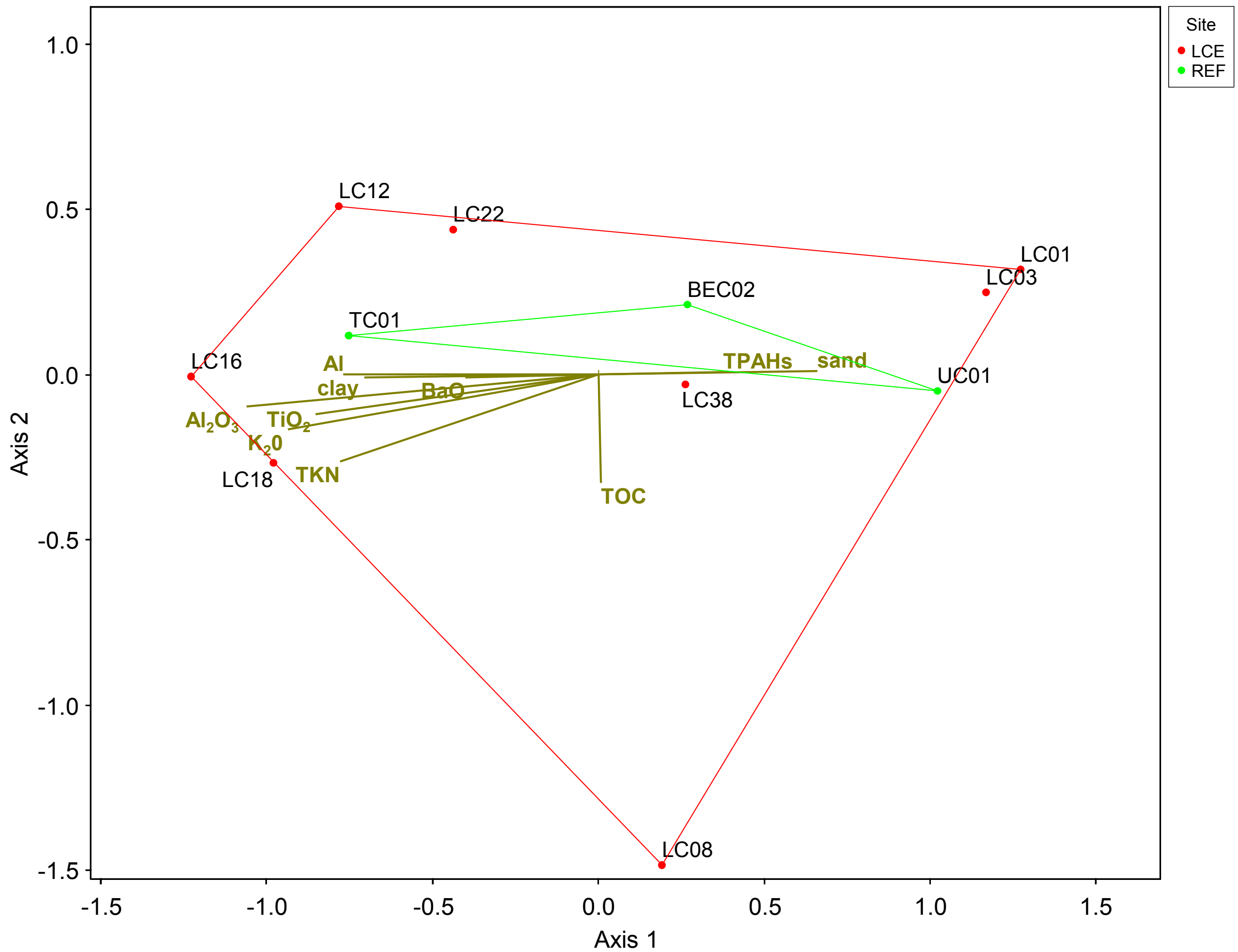


Figure 16B. Correlation of explanatory (environmental) variables to 2015 Lyons Creek East and reference creek site scores. Variables with combined r^2 values of ≥ 0.2 are shown as vectors. Sample scores for Lyons Creek East (red) and neighbouring reference creeks (green) are enclosed by polygons to show group separation. LC= Lyons Creek, TC= Tee Creek, UC=Usshers Creek, BEC=Beaver Creek.

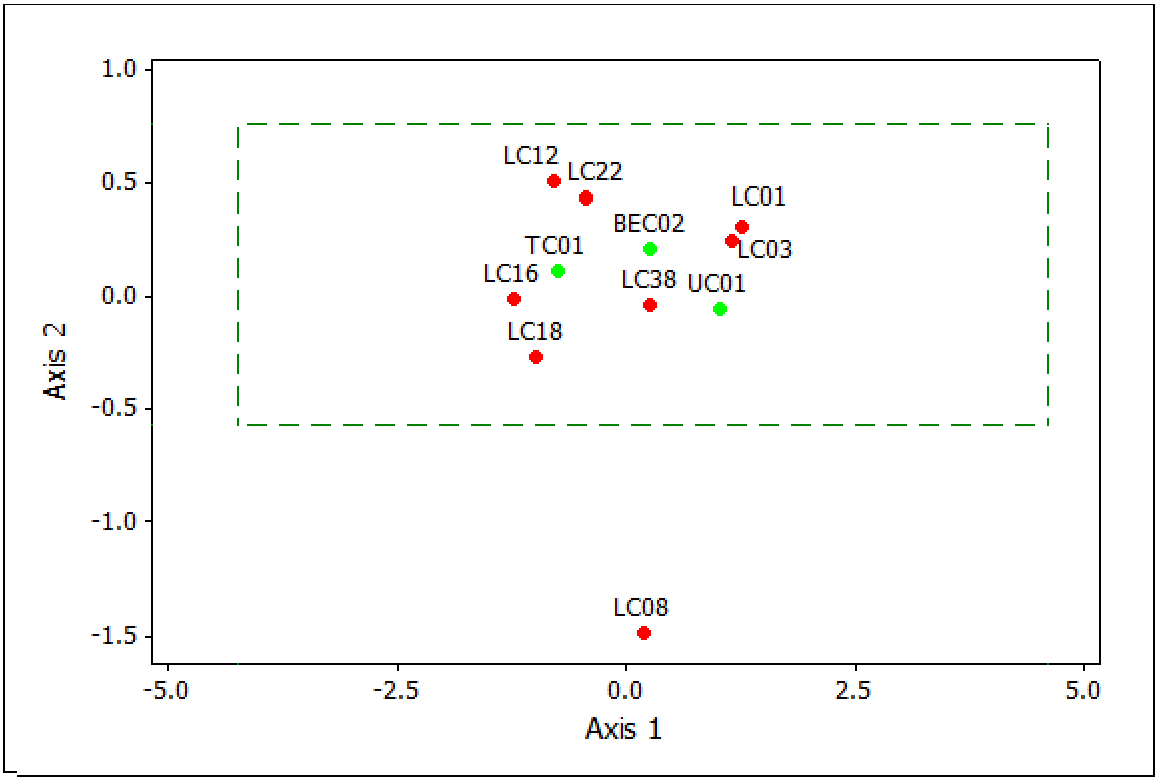


Figure 16C. 95% prediction intervals for reference site scores indicated by the dashed box for NMS axes 1 and 2.

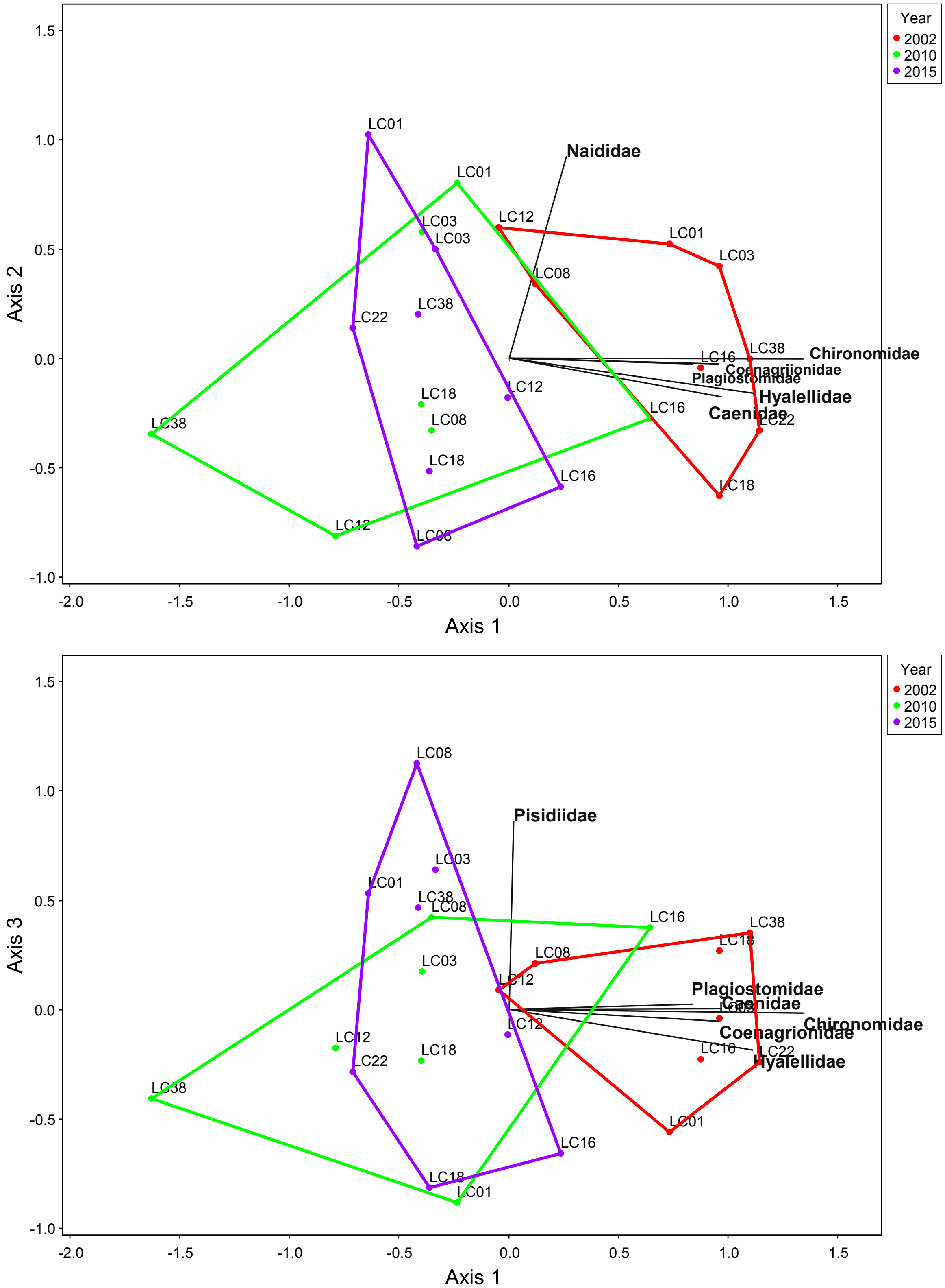


Figure 17A. Representation of time series for benthic macroinvertebrate community composition for Lyons Creek East summarized on axes 1 and 2 (top) and 1 and 3 (bottom). Final stress = 10.26. Families with combined r^2 values of ≥ 0.40 are shown as vectors. Sample scores for 2002 (red), 2010 (green) and 2015 (purple) are enclosed by polygons to show group separation. LC= Lyons Creek, TC = Tee Creek, UC = Usshers Creek, BEC = Beaver Creek.

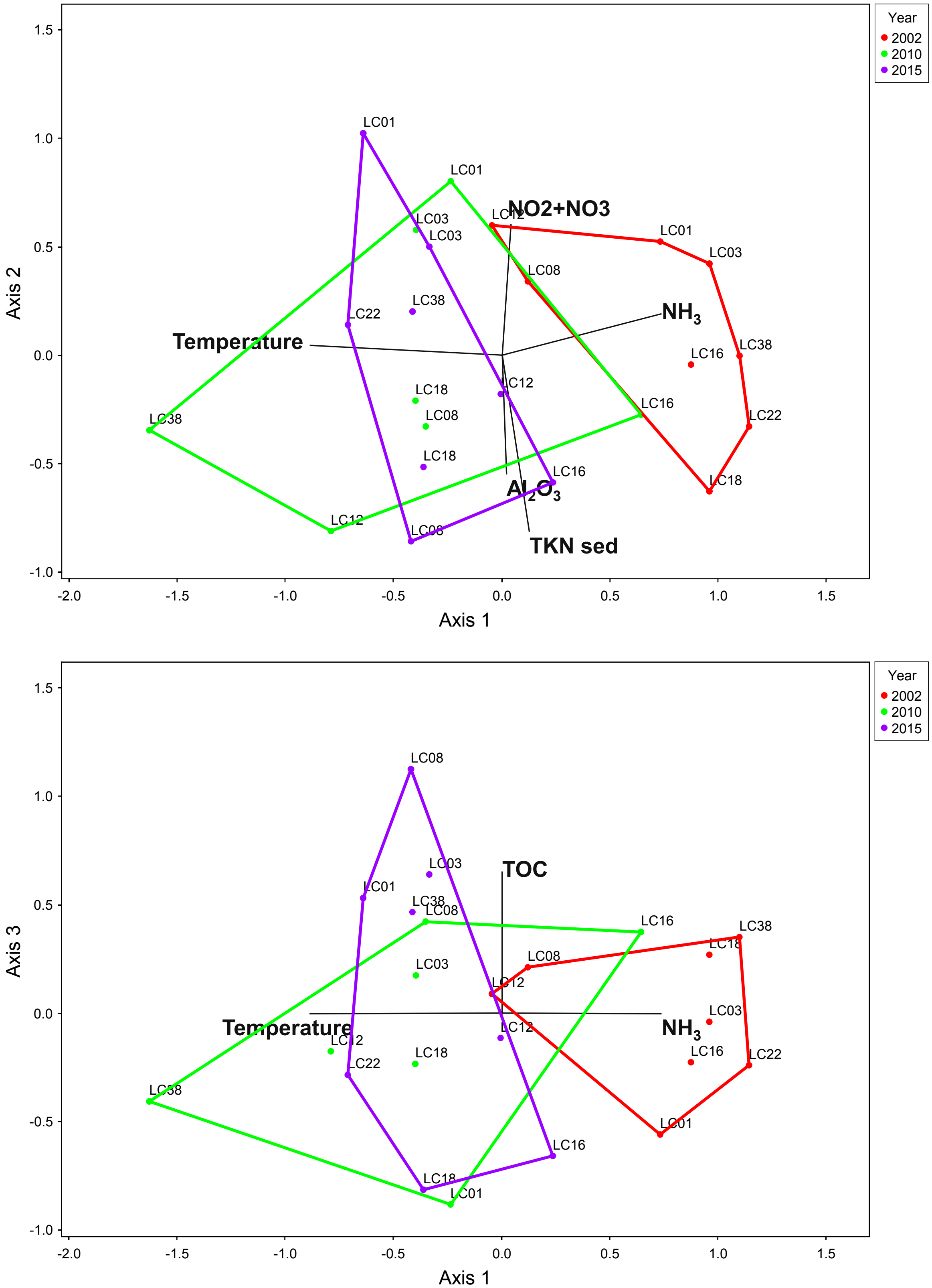


Figure 17B. Correlation of explanatory (environmental) variables to ordination axes from NMS of time series data (2002, 2010, and 2015) summarized on axes 1 and 2 (top) and 1 and 3 (bottom). Variables with combined r^2 values of ≥ 0.3 are shown as vectors. Sample scores for 2002 (red), 2010 (green) and 2015 (purple) are enclosed by polygons to show group separation. LC= Lyons Creek, TC = Tee Creek, UC = Usshers Creek, BEC = Beaver Creek.

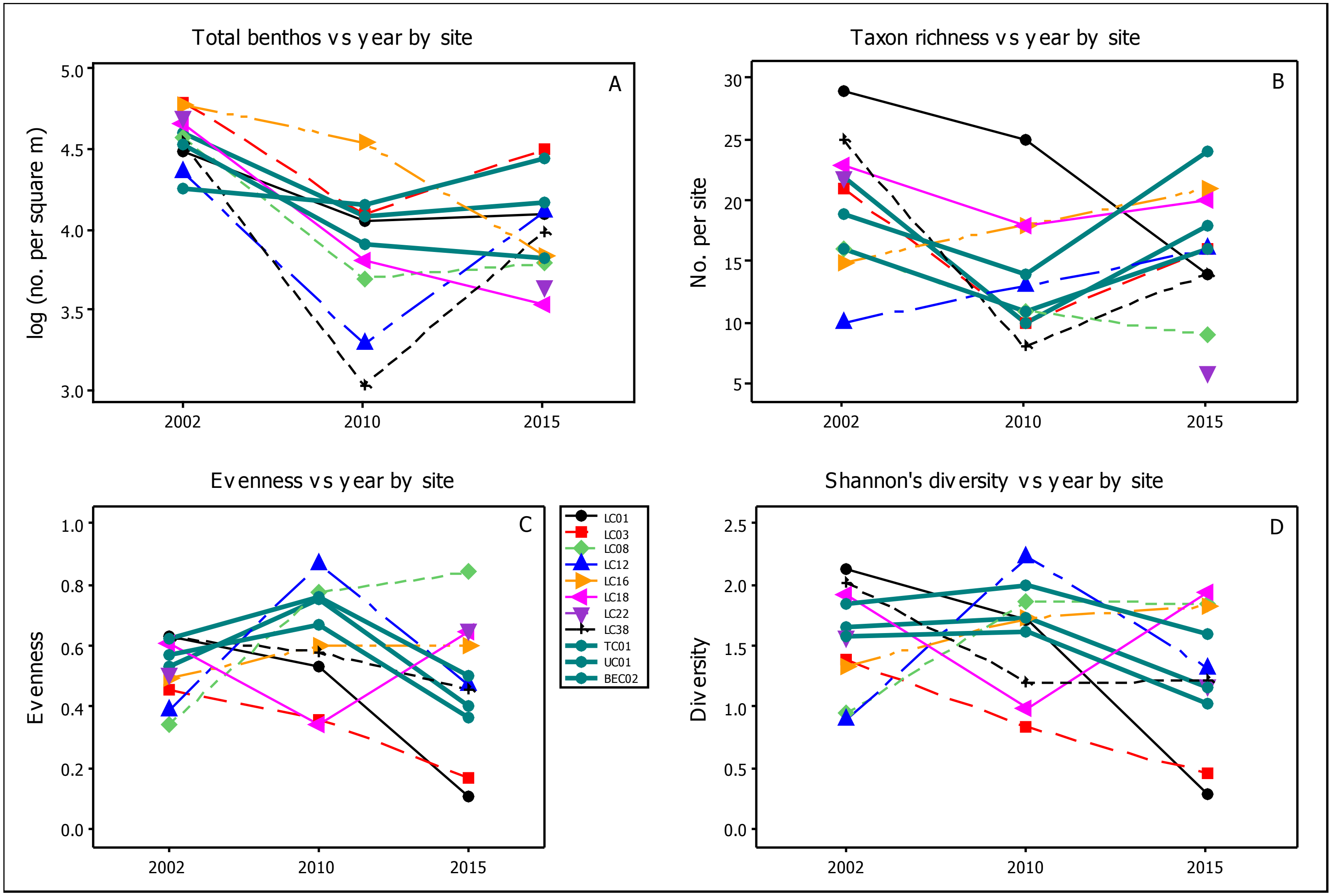


Figure 18. Trends in (A) total benthos (logged total number of individuals per m^2), (B) taxon richness, (C) Pielou's evenness (= Shannon diversity / ln (richness)), and (D) Shannon diversity index from co-located Lyons Creek East sites and reference sites (solid green lines) sampled 2002-2015. LC= Lyons Creek, TC = Tee Creek, UC = Usshers Creek, BEC = Beaver Creek.

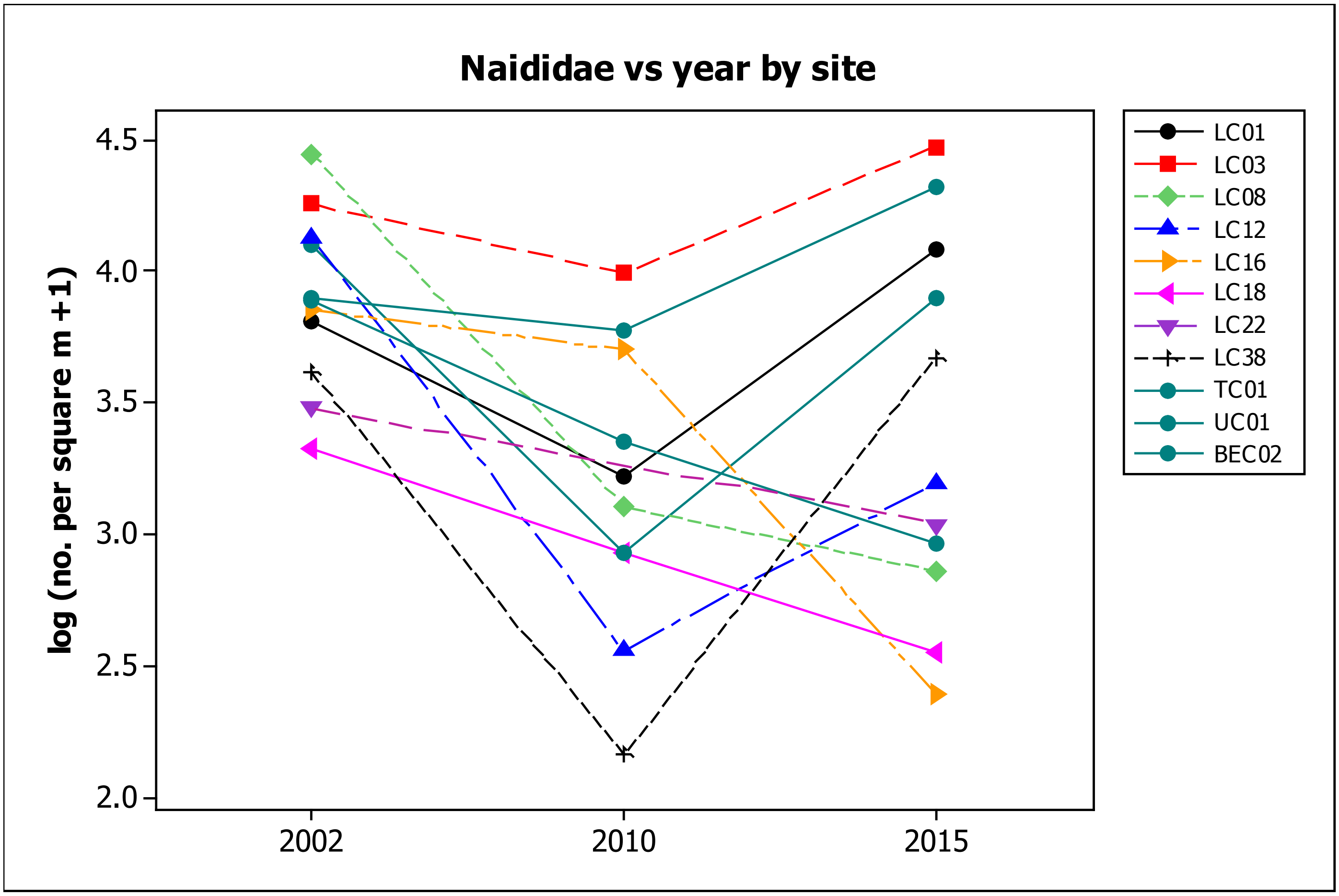


Figure 19. Trends in densities of naidid worms (log ×+1) from co-located Lyons Creek East sites and reference sites (solid green lines) sampled 2002-2015. LC= Lyons Creek, TC = Tee Creek, UC = Usshers Creek, BEC = Beaver Creek.

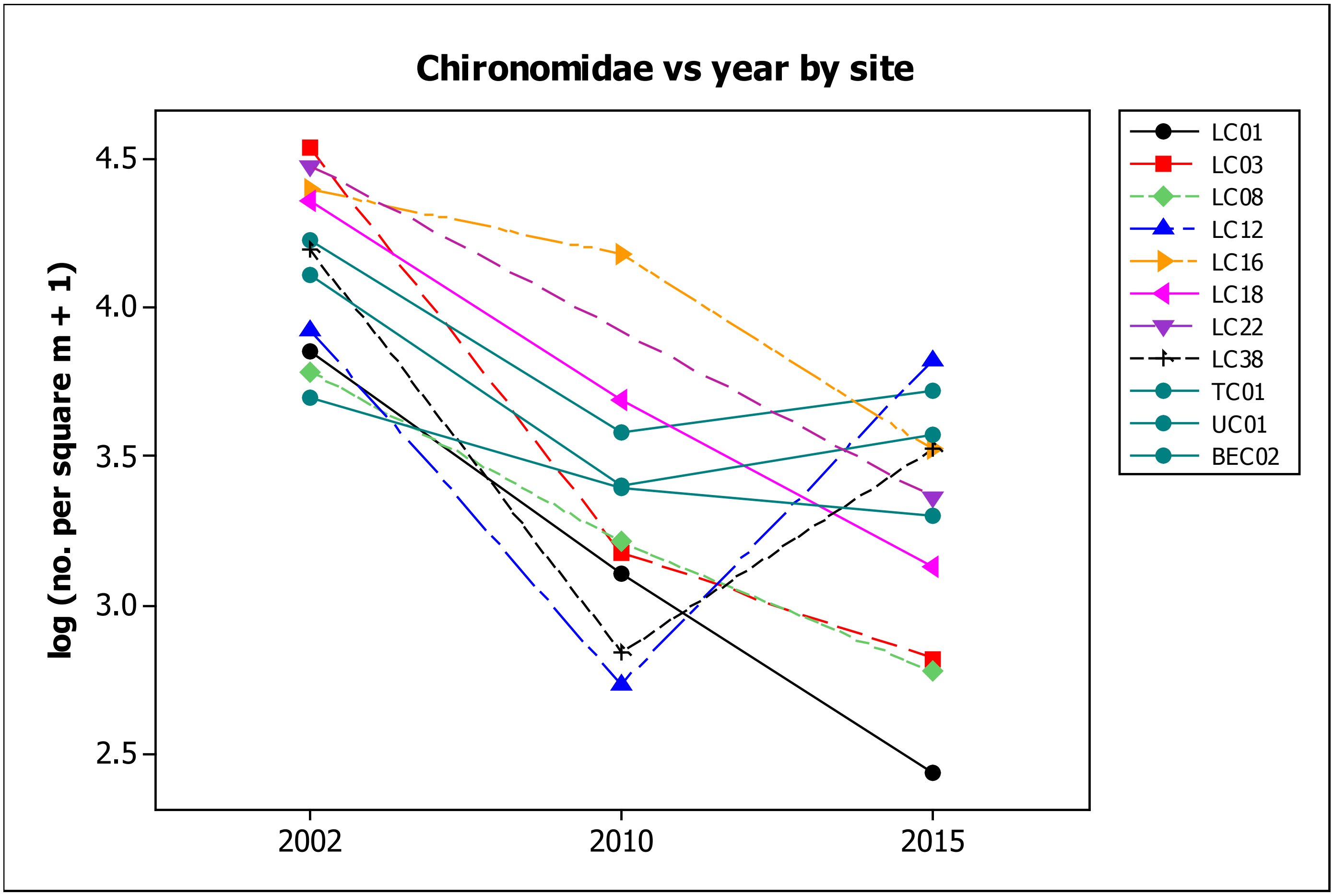


Figure 20. Trends in densities of chironomids (larval midges) (log ×+1) from co-located Lyons Creek East sites and reference (solid green lines) sampled 2002-2015. LC= Lyons Creek, TC = Tee Creek, UC = Usshers Creek, BEC = Beaver Creek.

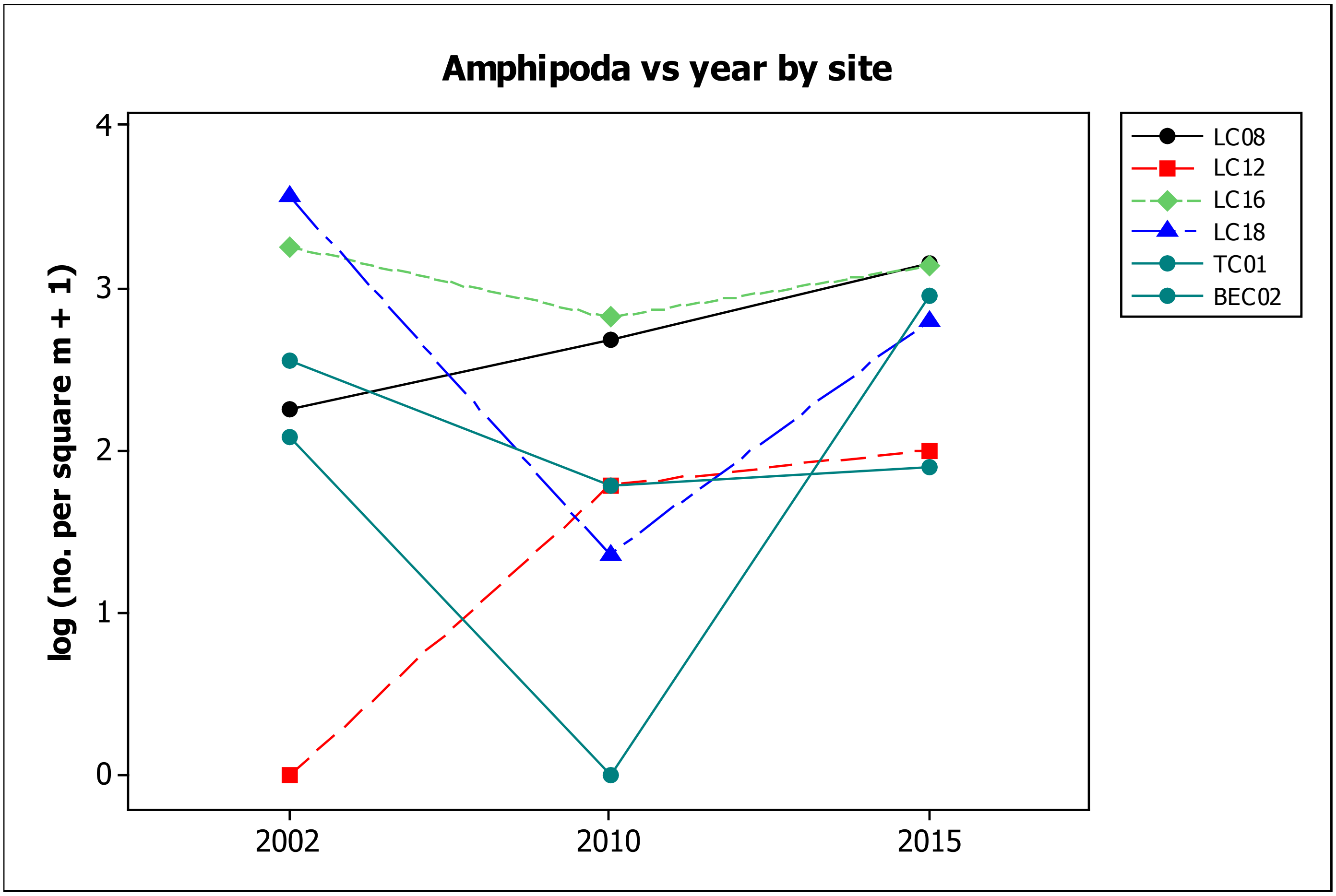


Figure 21. Trends in densities of amphipods (log ×+1) from co-located Lyons Creek East sites and reference sites (solid green lines) sampled 2002-2015. Note: some sites were removed due to the absence of amphipods in core or grab samples but their presence in sweeps (see text for details). LC= Lyons Creek, TC = Tee Creek, BEC = Beaver Creek.

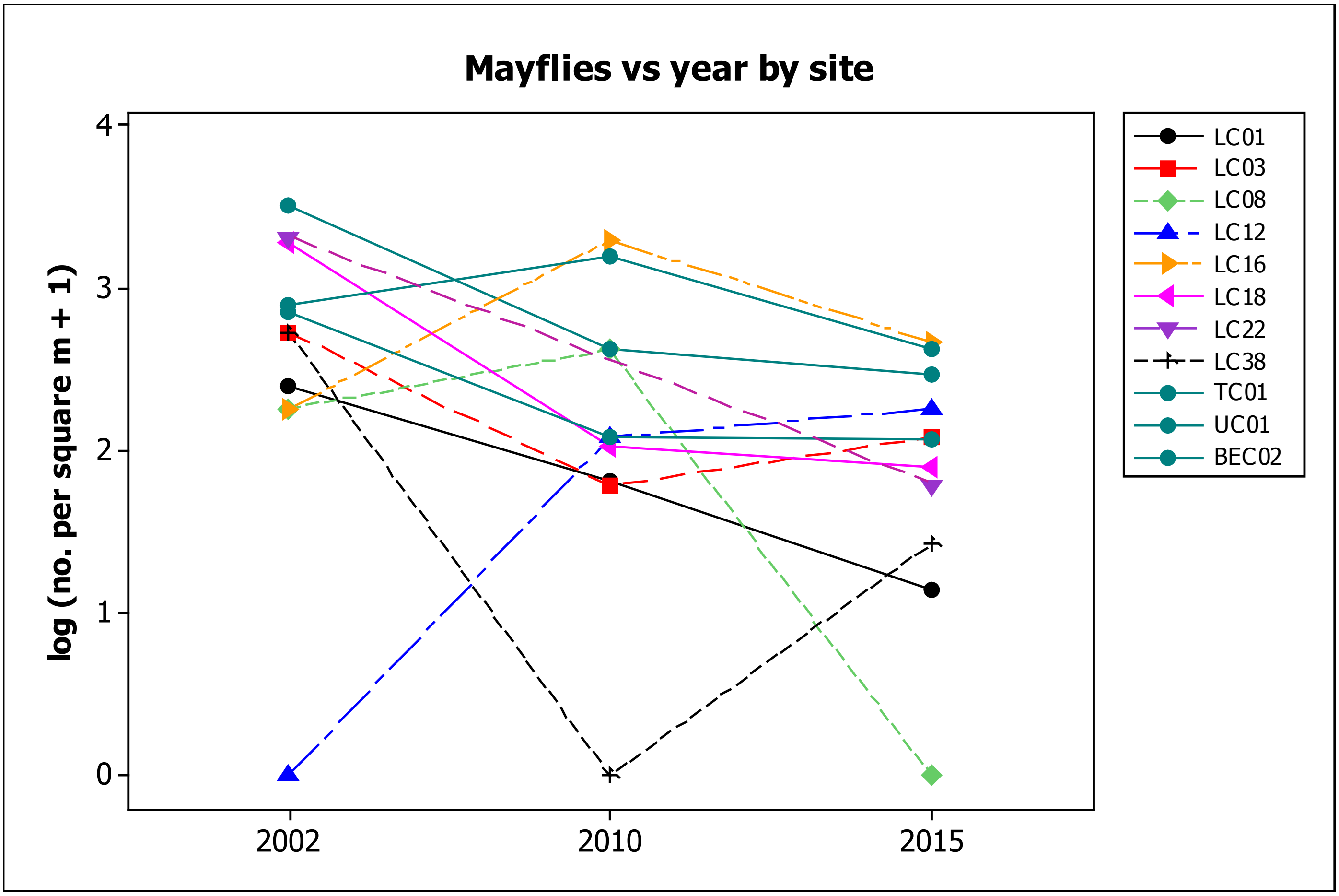


Figure 22. Trends in densities of mayflies (log ×+1) from co-located Lyons Creek East sites and reference sites (solid green lines) sampled 2002-2015. LC= Lyons Creek, TC = Tee Creek, UC = Usshers Creek, BEC = Beaver Creek.

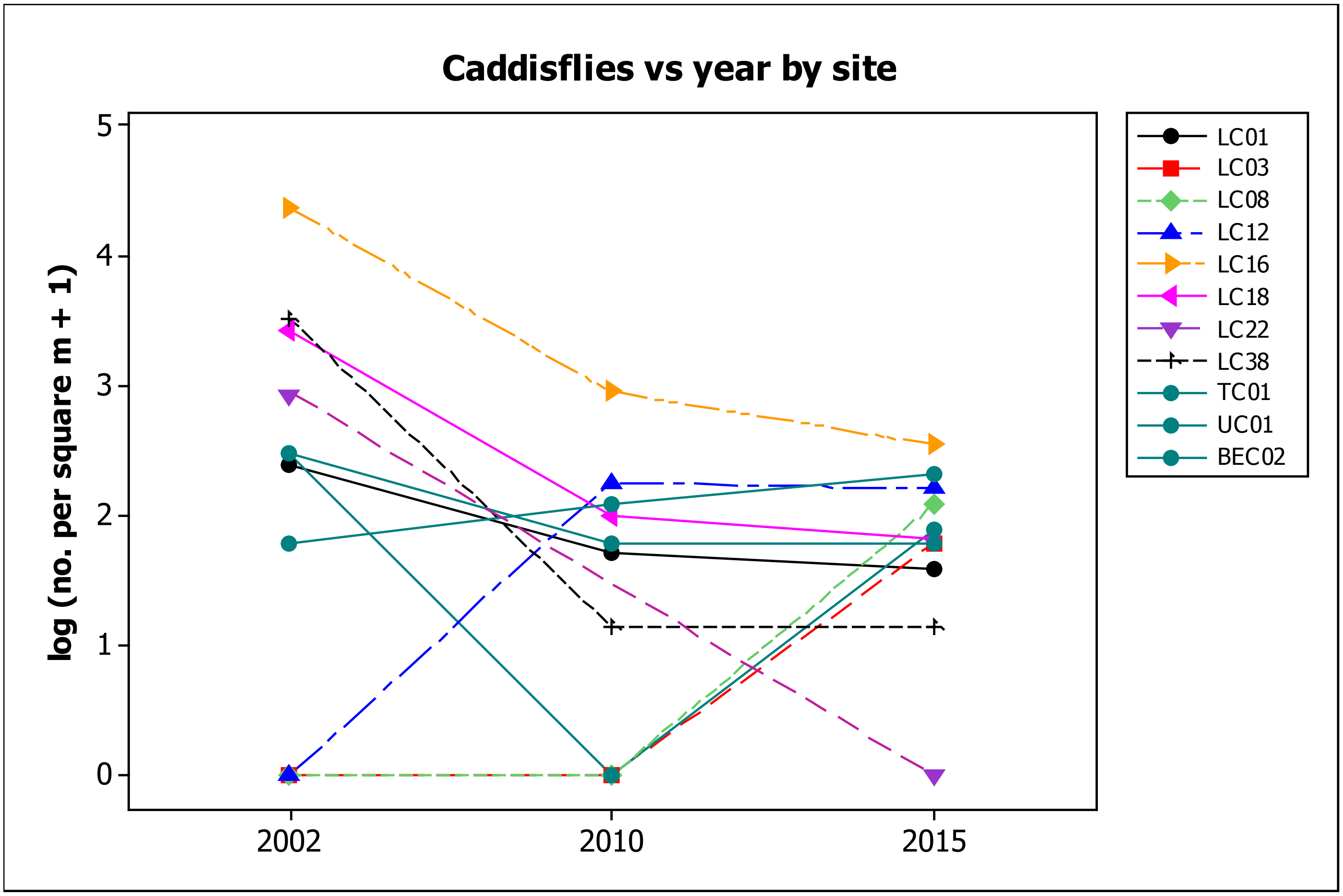


Figure 23. Trends in densities of caddisflies (log ×+1) from co-located Lyons Creek East sites and reference sites (solid green lines) sampled 2002-2015. LC= Lyons Creek, TC = Tee Creek, UC = Usshers Creek, BEC = Beaver Creek.

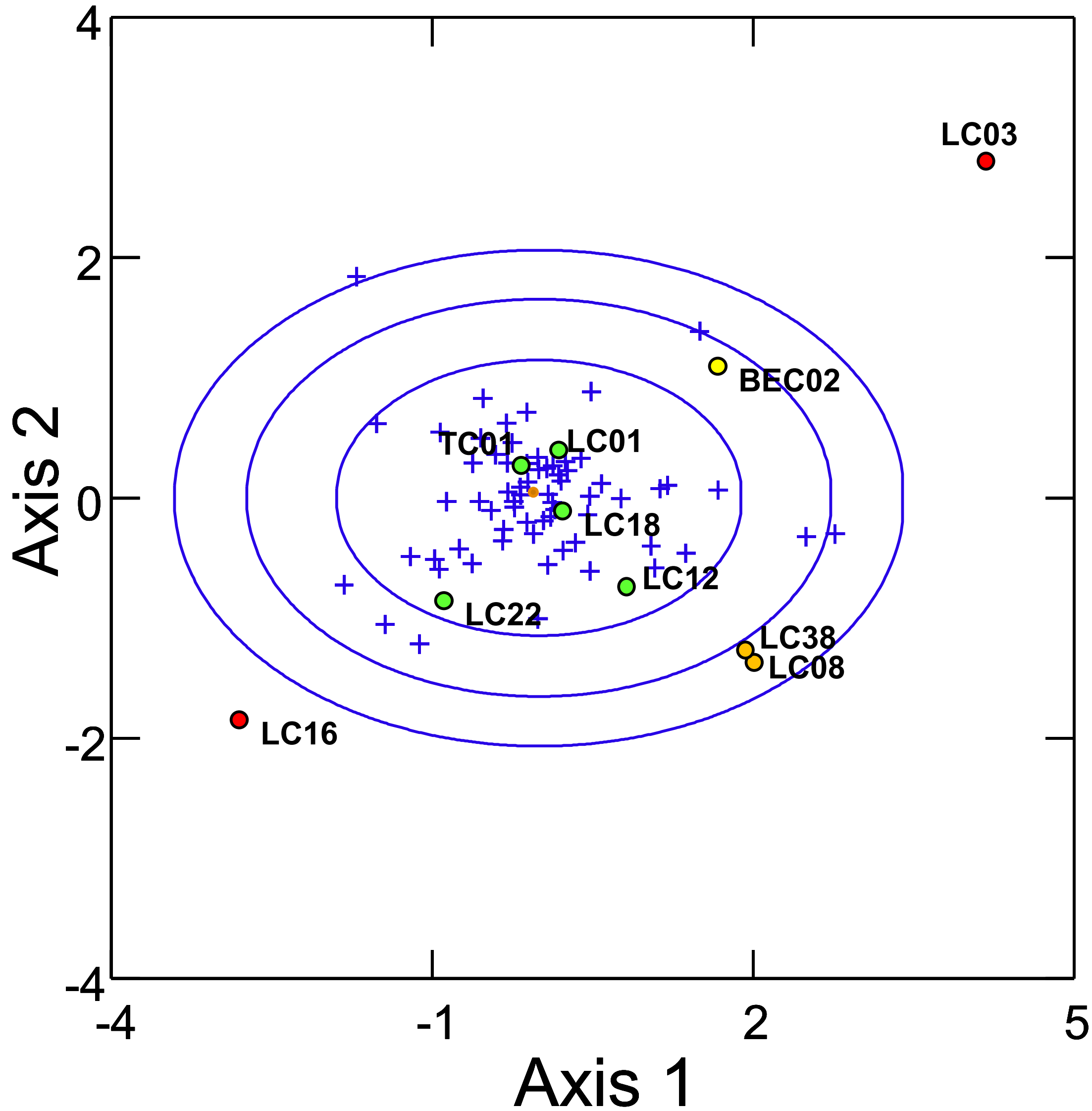


Figure 24. Two-dimensional nonmetric multidimensional scaling solution of toxicological endpoints for 2015 Lyons Creek East and local reference creek sites (n=10) fitted into Great Lakes reference site (cross hairs) ordination space. Final stress = 12.30. Three confidence ellipses (90, 99, 99.9%) constructed around the Great Lakes reference sites define the four assessment bands. Band 1 (within 90%) = non-toxic (green), Band 2 (between 90% and 99%) = potentially toxic (yellow), Band 3 (between 99 and 99.9%) = toxic (orange), and Band 4 (outside the 99.9%) = severely toxic (red). LC= Lyons Creek, TC = Tee Creek, BEC = Beaver Creek.

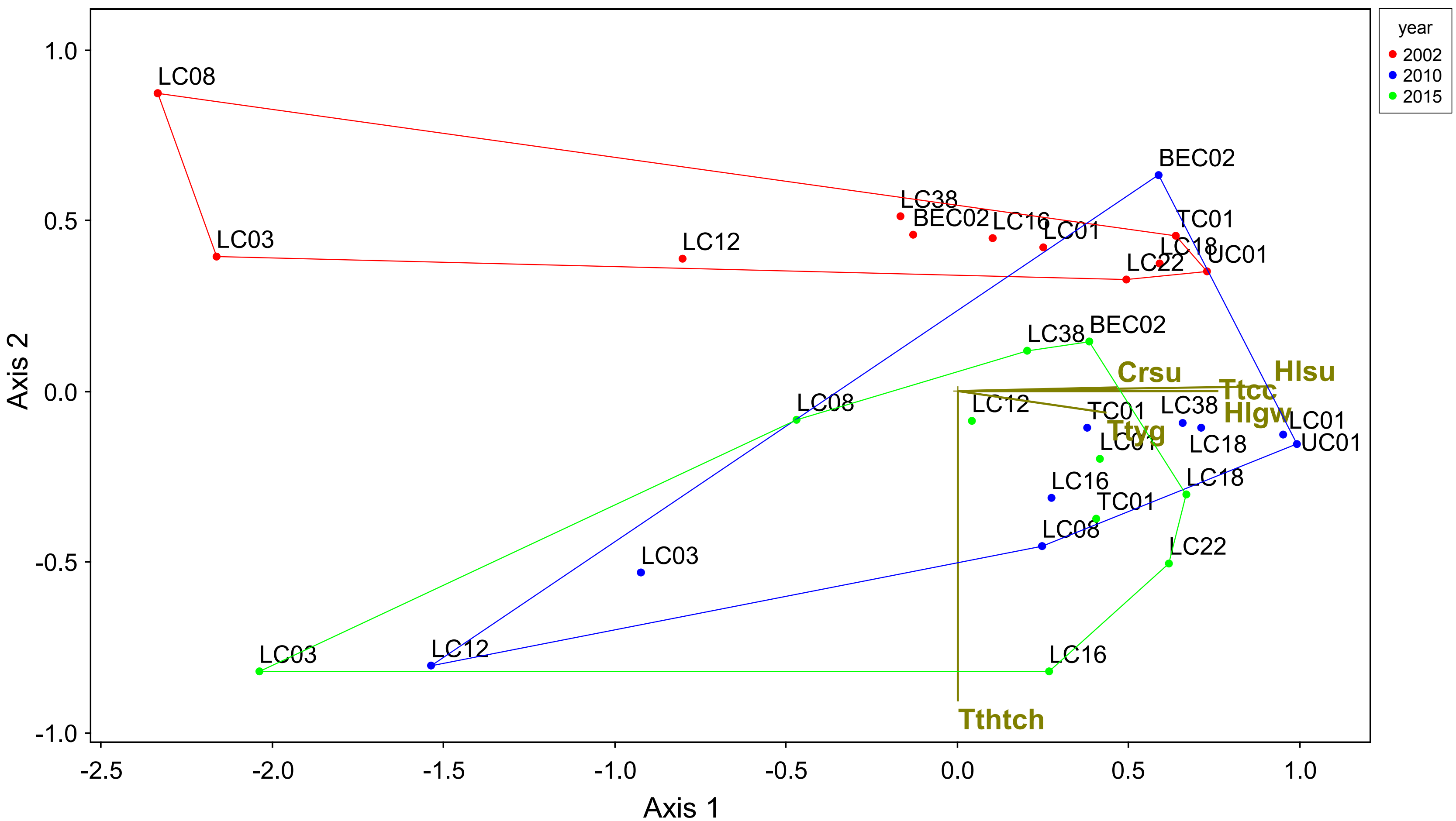


Figure 25A. Representation toxicological response of time series for Lyons Creek East and neighbouring reference creeks. Final stress = 11.12 for a 2-dimensional solution. The association of individual endpoints with combined $r^2 \geq 0.4$ to the NMS axes are shown as vectors (scaled to 60%). Sample scores for 2002 (red), 2010 (blue) and 2015 (green) are enclosed by polygons to show group separation. Hasu = *Hyalella* survival, Hlsu = *Hexagenia* survival, Crsu = Chironomus survival, Hlgw = *Hexagenia* growth, Ttcc = *Tubifex* cocoon production, Tthtch = *Tubifex* % hatched cocoons, Ttyg = *Tubifex* young production. LC= Lyons Creek, TC = Tee Creek, UC = Usshers Creek, BEC = Beaver Creek.

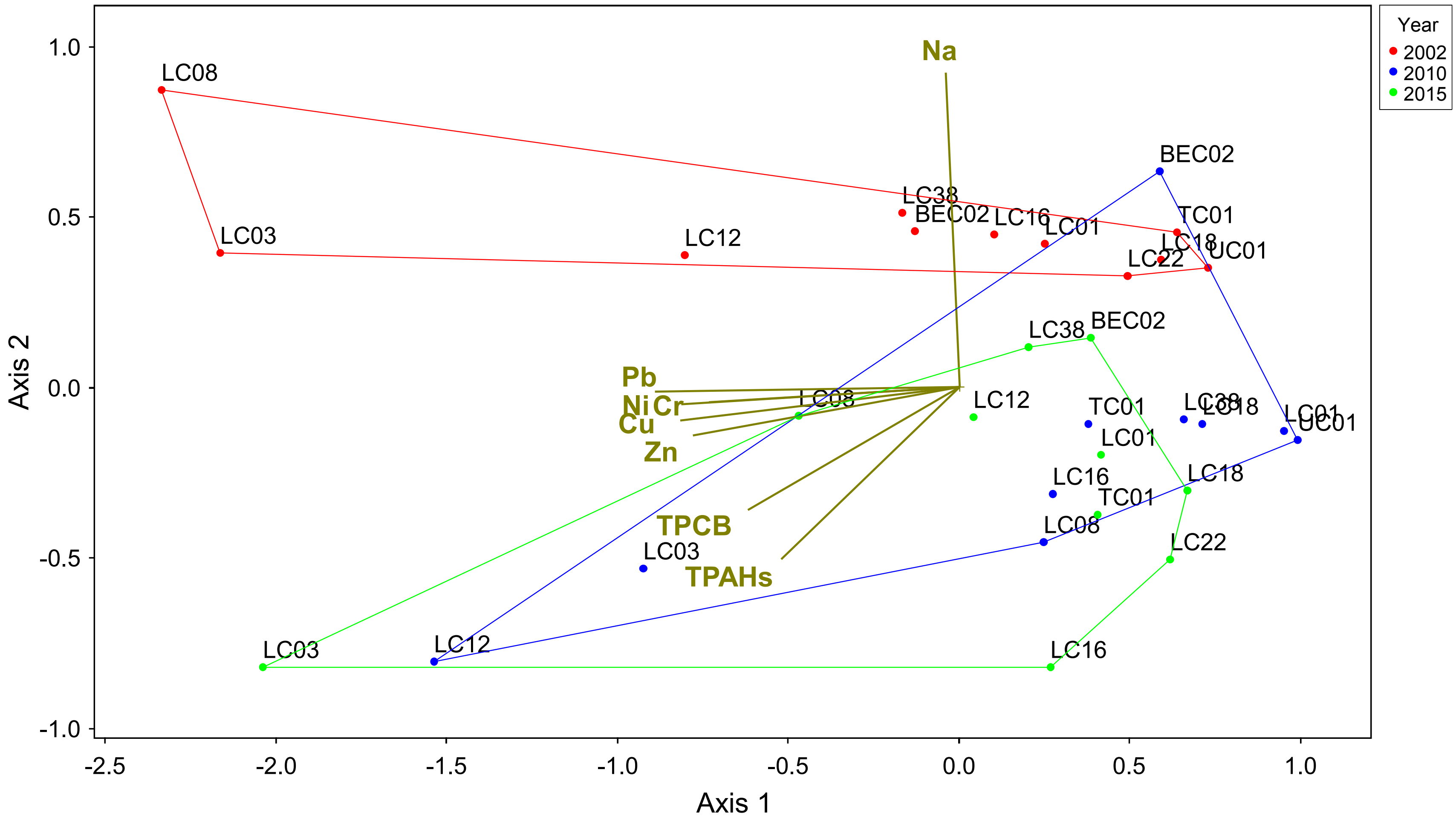


Figure 25B. Correlation between explanatory (environmental) variables to ordination axes from NMS of time series data (2000, 2010, and 2015). Variables with overall a combined $r^2 \geq 0.4$ are shown as vectors. Sample scores for 2002 (red), 2010 (blue), and 2015 (green) are enclosed by polygons to show group separation. LC= Lyons Creek, TC = Tee Creek, UC = Usshers Creek, BEC = Beaver Creek.

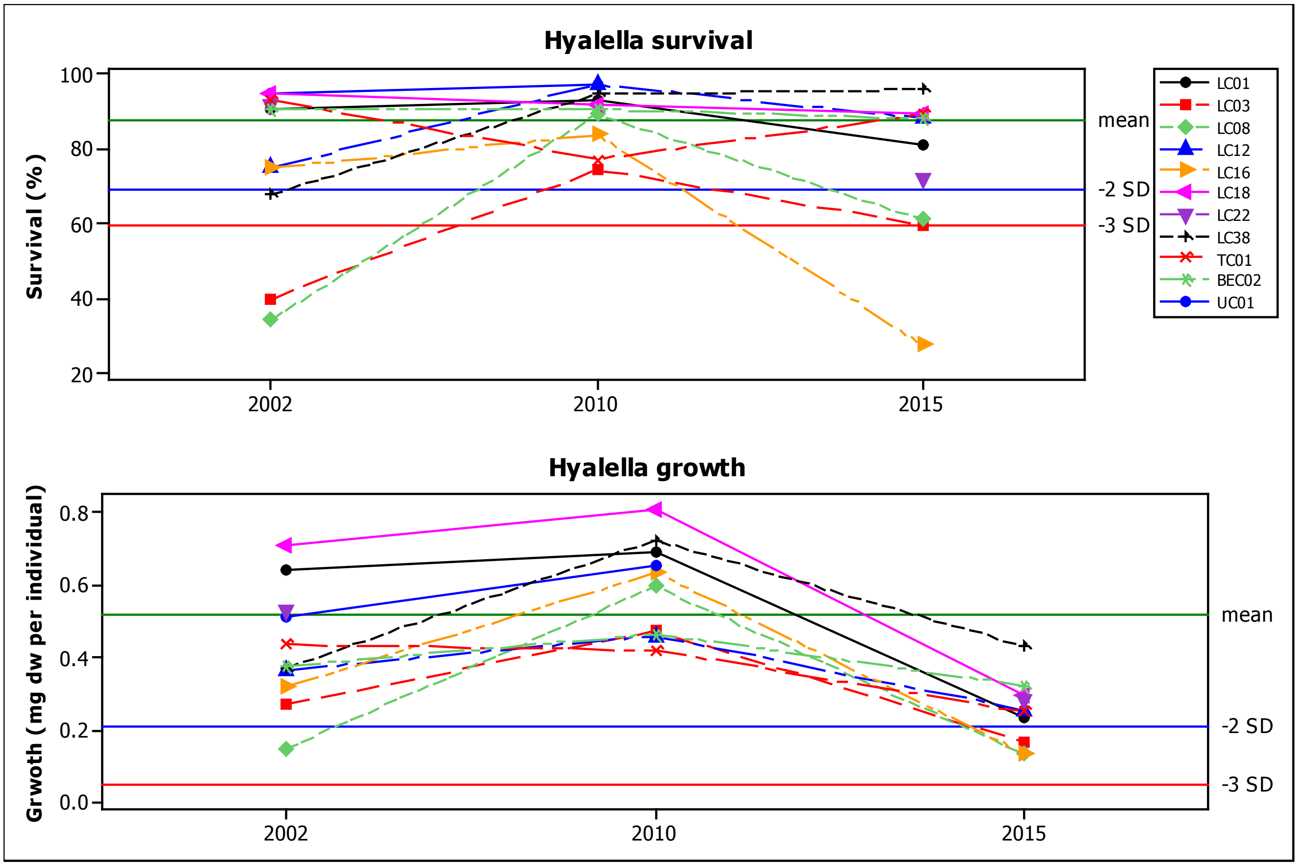


Figure 26. Trends in *Hyalella azteca* survival and growth for co-located Lyons Creek East and neighbouring reference creek sites sampled 2002-2015. The green horizontal line represents the Great Lakes reference mean, and the blue and red lines minus 2 and 3 standard deviations (SD) from the mean. LC= Lyons Creek, TC = Tee Creek, BEC = Beaver Creek, UC = Usshers Creek.

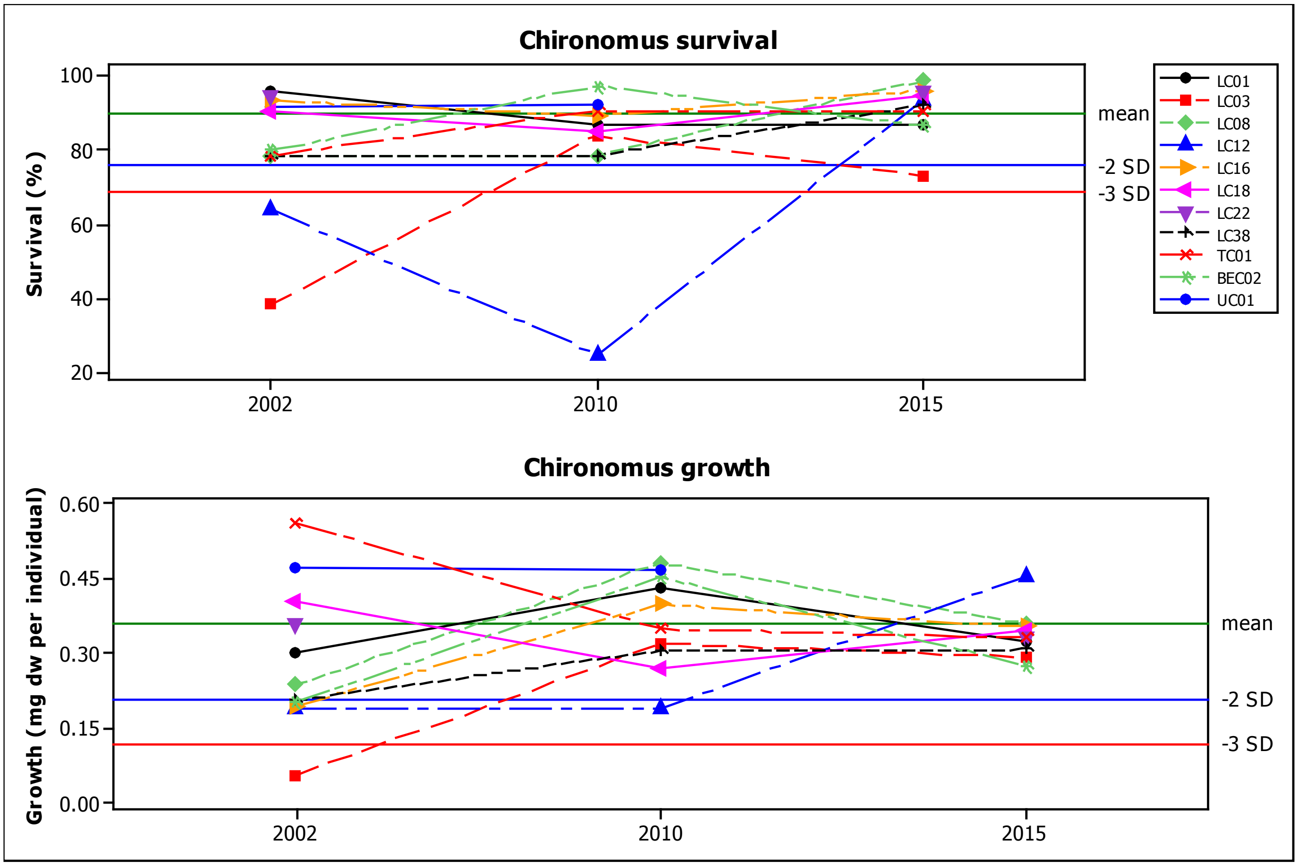


Figure 27. Trends in *Chironomus riparius* survival and growth for co-located Lyons Creek East and neighbouring reference creek sites sampled 2002-2015. The green horizontal line represents the Great Lakes reference mean, and the blue and red lines minus 2 and 3 standard deviations (SD) from the mean. LC= Lyons Creek, TC = Tee Creek, BEC = Beaver Creek, UC = Usshers Creek.

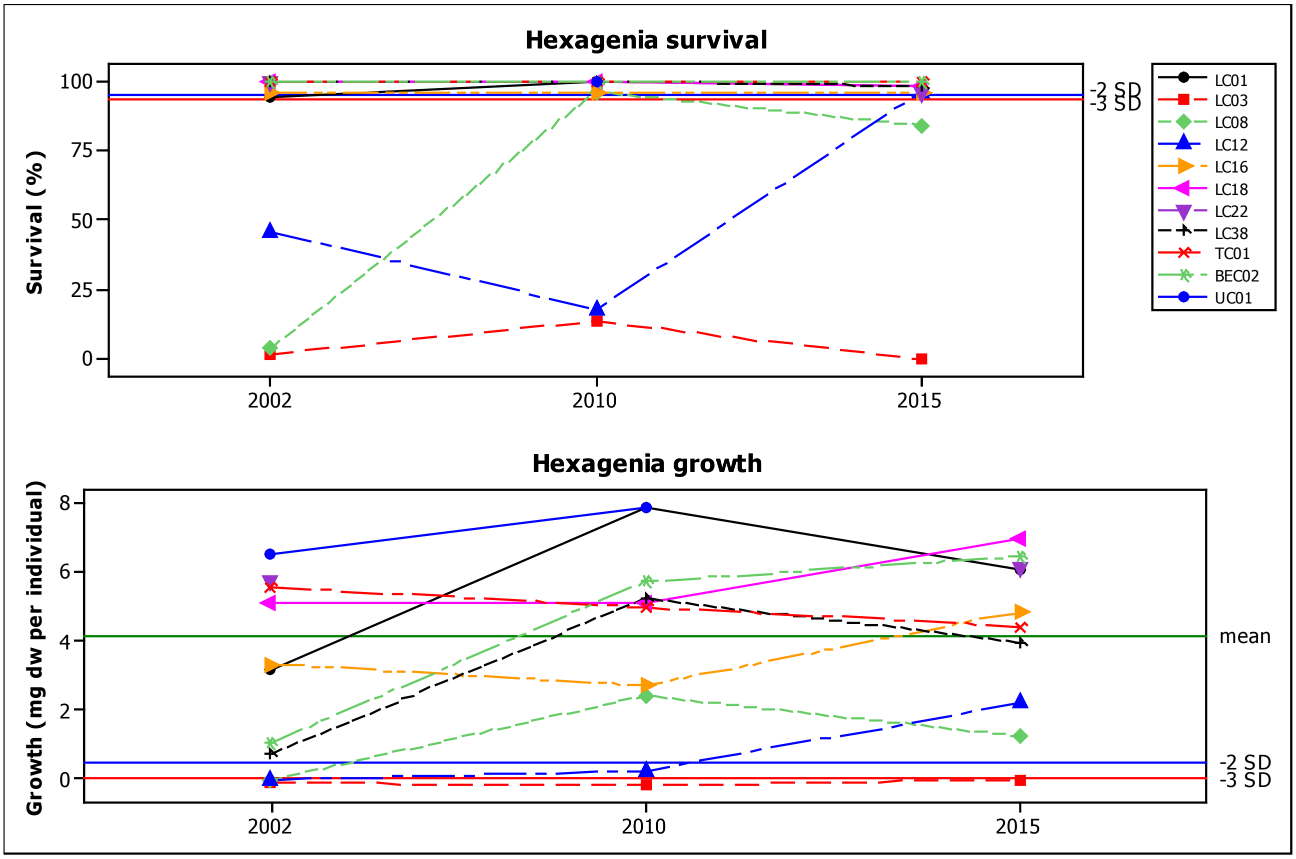


Figure 28. Trends in *Hexagenia* spp. survival and growth for co-located Lyons Creek East and neighbouring reference creek sites sampled 2002-2015. The green horizontal line represents the Great Lakes reference mean, and the blue and red lines minus 2 and 3 standard deviations (SD) from the mean. LC= Lyons Creek, TC = Tee Creek, BEC = Beaver Creek, UC = Usshers Creek.

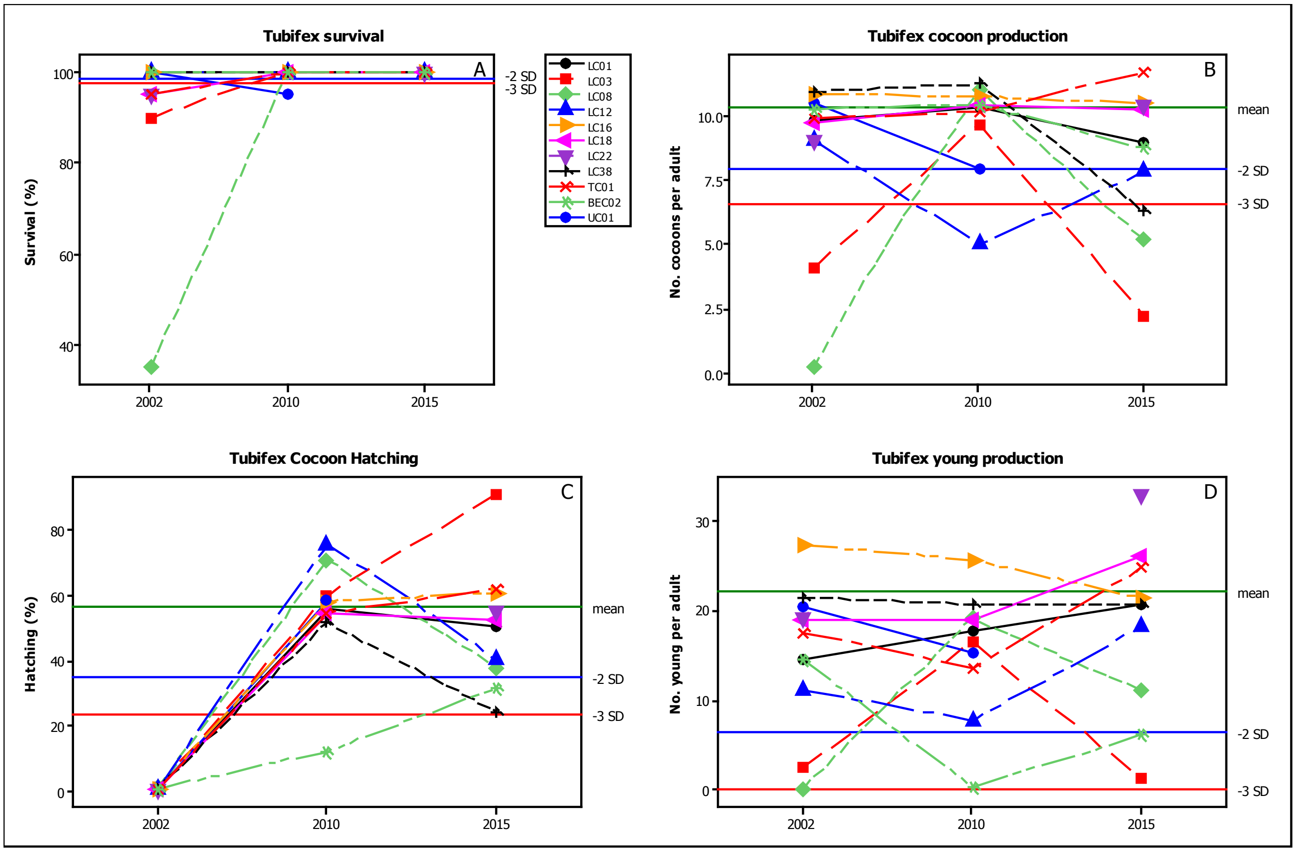


Figure 29. Trends in *Tubifex tubifex* (A) survival, (B) cocoon production, (C) cocoon hatching, and (D) young production for co-located Lyons Creek East and neighbouring reference creek sites sampled 2002-2015. The green horizontal line represents the Great Lakes reference mean, and the blue and red lines minus 2 and 3 standard deviations (SD) from the mean. LC= Lyons Creek, TC = Tee Creek, BEC = Beaver Creek, UC = Usshers Creek.

APPENDIX A

Quality assurance/Quality control

Table A1. Variation (coefficient of variation, CV) in trace metal, metal oxides and nutrient analysis for Lyons Creek East QA/QC sample.

Parameter	Units	M.D.L.	LCE-LC1200	LCE-LC1201	LCE-LC1202	CV
Aluminum	µg/g	10	15500	15700	15700	0.7
Antimony	µg/g	0.5	0.6	0.9	0.7	20.8
Arsenic	µg/g	0.5	7.9	12.2	9.2	22.6
Barium	µg/g	1	118	131	122	5.4
Beryllium	µg/g	0.2	0.8	0.8	0.8	0.0
Bismuth	µg/g	5	< 5	< 5	< 5	nc
Cadmium	µg/g	0.5	0.6	0.8	0.6	17.3
Calcium	µg/g	10	34300	38100	42400	10.6
Chromium	µg/g	1	34	36	34	3.3
Cobalt	µg/g	1	12	12	12	0.0
Copper	µg/g	1	59	63	59	3.8
Iron	µg/g	10	29600	34400	31900	7.5
Lead	µg/g	5	42	51	43	10.9
Magnesium	µg/g	10	8440	8280	8710	2.6
Manganese	µg/g	1	288	292	296	1.4
Mercury	µg/g	0.005	0.108	0.129	0.111	9.8
Molybdenum	µg/g	1	1	2	1	43.3
Nickel	µg/g	1	46	53	46	8.4
Phosphorus	µg/g	5	833	1160	1030	16.3
Potassium	µg/g	30	1940	1960	2020	2.1
Silver	µg/g	0.2	7	9.1	8.2	13.0
Sodium	µg/g	20	220	220	220	0.0
Silicon	µg/g	1	241	223	260	7.7
Strontium	µg/g	1	107	122	131	10.1
Tin	µg/g	5	< 5	< 5	< 5	nc
Titanium	µg/g	1	171	163	179	4.7
Vanadium	µg/g	1	29	30	30	1.9
Yttrium	µg/g	0.5	10.6	10.4	10.6	1.1
Zinc	µg/g	3	581	988	678	28.4
Zirconium	µg/g	0.1	2.5	2.5	2.4	2.3
Aluminum (Al2O3)	%	0.04	11.4	11.9	12	2.7
Barium (BaO)	%	0.002	0.04	0.043	0.043	4.1
Calcium (CaO)	%	0.06	5.4	6.25	6.85	11.8
Chromium (Cr2O3)	%	0.006	0.015	0.016	0.015	3.8
Iron (Fe2O3)	%	0.01	5.31	6.24	5.9	8.1
Potasium (K20)	%	0.2	2.3	2.4	2.5	4.2
Magnesium (MgO)	%	0.03	2.05	2.17	2.19	3.5
Manganese (MnO)	%	0.003	0.059	0.066	0.065	6.0
Sodium (Na2O)	%	0.5	0.8	0.8	0.9	6.9
Phosphorus (P2O5)	%	0.5	< 0.5	< 0.5	< 0.5	nc
Silica (SiO2)	%	0.1	51.6	53.1	54.1	2.4
Titanium (TiO2)	%	0.02	0.7	0.71	0.72	1.4
Whole Rock Total	%		98.2	103	104	3.0
TC (LOI@1000°C)	%	0.05	18.3	18.8	18.4	1.4
Total Kjeldahl Nitrogen	µg/g	5	6480	6140	6260	2.7
Phosphorus-Total	µg/g	1	912	1230	1170	15.3
Total Organic Carbon	%	0.1	5.3	5.3	5.4	1.1
Mean: 7.6 %;						
Range: 0-43.3 %						

Table A2. Coefficients of variation (CV) for field-replicated site (LC12) – sediment petroleum hydrocarbons.

Analyte	LC1200	LC1201	LC1202	CV
Benzene	<0.110	<0.110	<0.110	nc
Ethylbenzene	<0.160	<0.160	<0.160	nc
m,p-Xylenes	0.970	<0.330	<0.330	nc
o-Xylene	0.920	<0.130	<0.130	nc
Toluene	0.940	0.420	1.610	60.3
Fraction 1 (C6-C10)	<10.2	<10.2	<10.2	nc
Fraction 2 (C10-C16)	23.9	72.9	27.1	66.4
Fraction 3 (C16-C34)	2040	3750	2570	31.4
Fraction 4 (C34-C50)	698	1310	915	31.8
Fraction 4 Gravimetric	4400	7960	5080	32.5

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

Table A3. Variation (coefficient of variation, CV) in PAH and total PCB analysis for 2015 field-replicated sediment samples (site LC12). NC = not calculable due to value(s) below limit of detection

	UNITS	LC1200	RDL	LC1201	RDL	LC1202	RDL	CV
Acenaphthene	ug/g	<0.05	0.05	0.096	0.02	0.03	0.03	74.1
Acenaphthylene	ug/g	0.03	0.02	<0.02	0.02	<0.03	0.03	nc
Anthracene	ug/g	0.058	0.02	0.2	0.02	0.073	0.03	70.7
Benzo(a)anthracene	ug/g	0.21	0.02	0.49	0.02	0.22	0.03	51.8
Benzo(a)pyrene	ug/g	0.22	0.02	0.37	0.02	0.19	0.03	37.1
Benzo(b/j)fluoranthene	ug/g	0.29	0.02	0.38	0.02	0.25	0.03	21.7
Benzo(g,h,i)perylene	ug/g	0.18	0.02	0.26	0.02	0.15	0.03	28.9
Benzo(k)fluoranthene	ug/g	0.071	0.02	0.079	0.02	0.065	0.03	9.8
Chrysene	ug/g	0.24	0.02	0.62	0.02	0.27	0.03	56.1
Dibenz(a,h)anthracene	ug/g	0.038	0.02	0.054	0.02	0.034	0.03	25.2
Fluoranthene	ug/g	0.49	0.02	1.1	0.02	0.59	0.03	45.0
Fluorene	ug/g	0.057	0.02	0.19	0.02	0.082	0.03	64.5
Indeno(1,2,3-cd)pyrene	ug/g	0.13	0.02	0.12	0.02	0.11	0.03	8.3
1-Methylnaphthalene	ug/g	<0.02	0.02	0.02	0.02	<0.03	0.03	nc
2-Methylnaphthalene	ug/g	0.19	0.02	0.18	0.02	0.2	0.03	5.3
Naphthalene	ug/g	0.02	0.02	0.026	0.02	<0.03	0.03	18.4
Phenanthrene	ug/g	0.14	0.02	0.18	0.02	0.14	0.03	15.1
Pyrene	ug/g	0.51	0.02	1.2	0.02	0.57	0.03	50.3
Total PCBs	ug/g	3.4	0.25	11	0.25	5.8	0.40	57.7

Mean: 37.6 %, Range: 5.3-74.1 %

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

Table A4. Coefficients of variation (CV) for field-replicated site (LC12) – sediment PCB congeners.

Sample Name	LC1200 (pg/g)	LC1201 (pg/g)	LC1202 (pg/g)	CV (%)	Sample Name	LC1200 (pg/g)	LC1201 (pg/g)	LC1202 (pg/g)
PCB-001	454	1250	527	59.2	PCB-111	<97	<200	<190
PCB-002	82.3	<83	<49	nc	PCB-120	<95	<230	<180
PCB-003	<890	2000	1040	44.7	PCB-108/124	3990	12100	6790
PCB-004	8470	59800	18200	94.6	PCB-107	8230	24200	18800
PCB-010	<310	2350	700	76.5	PCB-123	3630	<10000	23500
PCB-009	920	4490	1640	80.3	PCB-106	<190	<880	<580
PCB-007	659	2400	907	71.2	PCB-118	139000	361000	206000
PCB-006	6590	30200	11200	78.2	PCB-122	2800	9210	5090
PCB-005	<110	<350	<350	nc	PCB-114	3860	<14000	8480
PCB-008	42200	171000	70400	71.6	PCB-105	77700	214000	118000
PCB-014	<200	<460	<290	nc	PCB-127	<180	<720	<470
PCB-011	<340	5060	1840	66.0	PCB-126	646	2180	1330
PCB-012/013	1970	4850	2170	53.7	PCB-155	<3.8	<0.80	<20
PCB-015	29300	96600	41300	64.4	PCB-152	<44	348	167
PCB-019	9990	56100	18800	86.5	PCB-150	<10	241	116
PCB-018/030	106000	717000	254000	88.8	PCB-136	6150	15200	8080
PCB-017	42800	270000	101000	85.6	PCB-145	49.1	95.1	<1.0
PCB-027	5880	38600	14600	86.0	PCB-148	36.6	62.8	33.6
PCB-024	<28	3860	1820	50.8	PCB-135/151	17800	32900	18700
PCB-016	40200	270000	96500	88.4	PCB-154	<5.1	<0.85	<1.0
PCB-032	28300	184000	67800	86.7	PCB-144	2400	5250	2900
PCB-034	<350	<2800	<1500	nc	PCB-147/149	36500	89900	52900
PCB-023	<290	<2500	<1300	nc	PCB-134/143	2680	8590	4840
PCB-026/029	22500	133000	51200	83.2	PCB-139/140	910	2600	1480
PCB-025	7280	45700	18600	82.7	PCB-131	778	2400	1280
PCB-031	140000	829000	325000	82.7	PCB-142	<270	<160	<120
PCB-020/028	189000	920000	388000	75.7	PCB-132	19100	47600	27200
PCB-021/033	79300	438000	197000	76.8	PCB-133	633	1650	1000
PCB-022	49900	289000	124000	79.3	PCB-165	<190	137	<96
PCB-036	1260	17200	7570	92.5	PCB-146	6020	14600	8870
PCB-039	<360	5630	2510	54.2	PCB-161	<180	<120	<89
PCB-038	<350	<2600	<1400	nc	PCB-153/168	38200	86800	54100
PCB-035	<370	4260	<1500	nc	PCB-141	9620	27500	15900
PCB-037	57000	225000	107000	66.5	PCB-130	3610	10400	5660
PCB-054	381	1790	677	78.3	PCB-137/164	9420	18200	10100
PCB-050/053	36100	176000	74300	75.7	PCB-129/138/163	63200	141000	80500
PCB-045/051	49700	237000	100000	75.2	PCB-160	<150	<100	<77
PCB-046	15700	79900	33800	76.7	PCB-158	4780	14800	8410
PCB-052	304000	1310000	590000	70.6	PCB-128/166	8530	23700	13900
PCB-073	<18	857000	385000	53.7	PCB-159	181	1060	638
PCB-043	10700	52300	24000	73.3	PCB-162	<150	401	234
PCB-049/069	163000	628000	295000	66.2	PCB-167	1720	5110	3060
PCB-048	59000	259000	117000	71.0	PCB-156/157	6250	16700	9580
PCB-044/047/065	288000	1130000	514000	67.7	PCB-169	<210	<200	<150
PCB-059/062/075	22300	86500	40100	66.8	PCB-188	<4.6	<7.0	5.74
PCB-042	79400	307000	148000	65.5	PCB-179	3950	9110	5630
PCB-040/041/071	163000	637000	295000	67.0	PCB-184	<8.2	<1.4	<5.8
PCB-064	122000	488000	228000	67.4	PCB-176	1070	2470	1540
PCB-072	<1300	<7200	<3500	nc	PCB-186	<5.8	<1.6	<1.0
PCB-068	<1100	<5800	<2900	nc	PCB-178	1910	4110	2510
PCB-057	<1300	<8200	4570	nc	PCB-175	377	735	450
PCB-058	4680	18100	8630	65.9	PCB-187	9520	21200	13400
PCB-067	<1000	15500	7390	50.1	PCB-182	<7.2	<1.9	<1.2
PCB-063	6980	29500	14200	68.1	PCB-183	5460	11600	7200
PCB-061/070/074/076	393000	1530000	720000	66.4	PCB-185	<7.8	<2.1	<1.3
PCB-066	262000	918000	475000	60.7	PCB-174	11700	23300	14500
PCB-055	<1200	<7300	<3600	nc	PCB-177	5440	12100	7560
PCB-056	120000	439000	213000	63.8	PCB-181	69	160	94.8
PCB-060	60500	244000	116000	67.1	PCB-171/173	2890	5990	3710
PCB-080	<1200	<6900	<3400	nc	PCB-172	1720	3760	2370
PCB-079	<1300	<6400	<3200	nc	PCB-192	<6.1	<1.6	<1.0
PCB-078	<1300	<7300	<3600	nc	PCB-180/193	24500	44900	28000
PCB-081	<1700	<9400	<4600	nc	PCB-191	<380	906	574
PCB-077	23200	67800	33300	56.4	PCB-170	11000	23100	14400
PCB-104	<21	<64	<31	nc	PCB-190	1870	4860	2990
PCB-096	2460	7860	3710	60.4	PCB-189	464	1130	716
PCB-103	800	2320	1260	53.4	PCB-202	823	2210	1470
PCB-094	1230	3720	1960	55.6	PCB-201	649	1290	828
PCB-095	122000	340000	180000	52.8	PCB-204	<5.5	1.36	1.17
PCB-093/098/100/102	10100	33000	17500	57.9	PCB-197	185	312	203
PCB-088/091	33200	101000	51700	56.6	PCB-200	637	1340	839
PCB-084	55700	165000	84800	55.6	PCB-198/199	7270	12400	7910
PCB-089	4950	15500	7890	57.6	PCB-196	3360	5880	3680
PCB-121	<93	<200	<180	nc	PCB-203	3840	7620	4830
PCB-092	23600	61400	34000	49.2	PCB-195	1610	6000	3890
PCB-090/101/113	142000	357000	198000	48.0	PCB-194	4910	17700	11400
PCB-083/099	119000	284000	163000	45.3	PCB-205	297	722	444
PCB-112	<99	<220	<200	nc	PCB-208	497	1300	824
PCB-086/087/097/109/119/1	134000	345000	189000	49.2	PCB-207	202	536	349
PCB-085/110/115/116/117	238000	641000	361000	50.0	PCB-206	2430	6860	4360
PCB-082	42300	118000	64800	51.8	PCB-209	335	820	465
Mean = 56.3%; Range = 10.6-103.6%; nc = not calculable								

Table A5. Relative percent difference (RPD) for 2015 LYONS CREEK EAST sample duplicates – metals and nutrients.

Parameter	Units	M.D.L.	LCE-LC16	LCE-LC16-DUP	R.P.D.
Aluminum	µg/g	10	18200	17400	4.5
Antimony	µg/g	0.5	0.6	< 0.5	0.0
Arsenic	µg/g	0.5	8.8	7.3	18.6
Barium	µg/g	1	128	125	2.4
Beryllium	µg/g	0.2	0.8	0.8	0
Bismuth	µg/g	5	< 5	< 5	0
Cadmium	µg/g	0.5	< 0.5	< 0.5	0
Calcium	µg/g	10	44600	45700	2.4
Chromium	µg/g	1	35	33	5.9
Cobalt	µg/g	1	12	11	8.7
Copper	µg/g	1	51	55	7.5
Iron	µg/g	10	34300	32800	4.5
Lead	µg/g	5	35	33	5.9
Magnesium	µg/g	10	10600	10300	2.9
Manganese	µg/g	1	374	363	3.0
Mercury	µg/g	0.005	0.096	0.096	0.0
Molybdenum	µg/g	1	< 1	1	0
Nickel	µg/g	1	44	43	2.3
Phosphorus	µg/g	5	995	990	0.5
Potassium	µg/g	30	2450	2300	6.3
Silver	µg/g	0.2	12.4	12.3	0.8
Sodium	µg/g	20	260	240	8.0
Silicon	µg/g	1	235	229	2.6
Strontium	µg/g	1	128	132	3.1
Tin	µg/g	5	< 5	< 5	0
Titanium	µg/g	1	163	156	4.4
Vanadium	µg/g	1	32	31	3.2
Yttrium	µg/g	0.5	10.2	9.9	3.0
Zinc	µg/g	3	651	629	3.4
Zirconium	µg/g	0.1	2.7	3.4	23.0
Aluminum (Al2O3)	%	0.04	13.5	13.1	3.0
Barium (BaO)	%	0.002	0.044	0.042	4.7
Calcium (CaO)	%	0.06	6.79	6.97	2.6
Chromium (Cr2O3)	%	0.006	0.014	0.013	7.4
Iron (Fe2O3)	%	0.01	6.61	6.25	5.6
Potasium (K20)	%	0.2	2.8	2.7	3.6
Magnesium (MgO)	%	0.03	2.69	2.6	3.4
Manganese (MnO)	%	0.003	0.091	0.079	14.1
Sodium (Na2O)	%	0.5	0.7	0.6	15.4
Phosphorus (P2O5)	%	0.5	< 0.5	< 0.5	0
Silica (SiO2)	%	0.1	51.2	48.9	4.6
Titanium (TiO2)	%	0.02	0.75	0.72	4.1
Whole Rock Total	%		105	102	2.9
TC (LOI@1000°C)	%	0.05	19.5	19.6	0.5
Total Kjeldahl Nitrogen	µg/g	5	6770	6690	1.2
Phosphorus-Total	µg/g	1	1130	1070	5.5
Total Organic Carbon	%	0.1	4.8	4.1	15.7
Mean = 4.7 %; Range = 0-23.0%					

Table A6. Relative percent difference (RPD) for 2015 LYONS CREEK EAST sample duplicates – PAHs and total PCBs.

QC Type	Parameter	Value	Recovery	UNITS	QC Limits
RPD	Acenaphthene	NC		%	40
	Acenaphthylene	NC		%	40
	Anthracene	NC		%	40
	Benzo(a)anthracene	NC		%	40
	Benzo(a)pyrene	NC		%	40
	Benzo(b/j)fluoranthene	NC		%	40
	Benzo(g,h,i)perylene	NC		%	40
	Benzo(k)fluoranthene	NC		%	40
	Chrysene	NC		%	40
	Dibenz(a,h)anthracene	NC		%	40
	Fluoranthene	NC		%	40
	Fluorene	NC		%	40
	Indeno(1,2,3-cd)pyrene	NC		%	40
	1-Methylnaphthalene	NC		%	40
	2-Methylnaphthalene	NC		%	40
	Naphthalene	NC		%	40
	Phenanthrene	NC		%	40
	Pyrene	NC		%	40
RPD	Aroclor 1242	NC		%	50
	Aroclor 1248	NC		%	50
	Aroclor 1254	NC		%	50
	Aroclor 1260	NC		%	50
	Total PCB	NC		%	50

Table A7. Relative percent difference (RPD) for 2015 sediment sample duplicates, PCB congeners.

Sample Name	TC01 (pg/g)	Duplicate	RPD (%)	Sample Name	TC01 (pg/g)	Duplicate	RPD (%)
PCB-001	20	19.9	0.5	PCB-111	<3.9	<4.4	
PCB-002	29.7	22.8	26.3	PCB-120	<3.8	<4.3	
PCB-003	31	25.8	18.3	PCB-108/124	<10	<11	
PCB-004	231	<210		PCB-107	<74	73.9	
PCB-010	<170	<180		PCB-123	<7.3	<4.7	
PCB-009	<190	<200		PCB-106	<6.4	<4.1	
PCB-007	<170	<180		PCB-118	1000	840	17.4
PCB-006	<160	<170		PCB-122	<19	<4.5	
PCB-005	<200	<210		PCB-114	<6.9	<4.6	
PCB-008	585	523	11.2	PCB-105	364	319	13.2
PCB-014	<29	<56		PCB-127	<6.1	<3.9	
PCB-011	<32	<63		PCB-126	15.4	13.3	14.6
PCB-012/013	<31	<60		PCB-155	<0.55	<0.49	
PCB-015	818	<110		PCB-152	<0.62	<0.58	
PCB-019	133	122	8.6	PCB-150	<1.7	<1.0	
PCB-018/030	1700	1690	0.6	PCB-136	86.4	74.5	14.8
PCB-017	531	512	3.6	PCB-145	<0.63	<0.59	
PCB-027	118	<120		PCB-148	<1.5	<1.2	
PCB-024	<9.5	<4.0		PCB-135/151	339	289	15.9
PCB-016	541	519	4.2	PCB-154	<0.68	<0.64	
PCB-032	263	253	3.9	PCB-144	28.6	25.3	12.2
PCB-034	<24	<28		PCB-147/149	797	686	15.0
PCB-023	<20	<23		PCB-134/143	41.5	31.5	27.4
PCB-026/029	200	179	11.1	PCB-139/140	11.4	10.2	11.1
PCB-025	<79	<21		PCB-131	<6.4	<3.3	
PCB-031	1370	1210	12.4	PCB-142	<5.0	<3.6	
PCB-020/028	3370	3130	7.4	PCB-132	264	227	15.1
PCB-021/033	1040	1010	2.9	PCB-133	<14	15.9	
PCB-022	539	488	9.9	PCB-165	<3.5	<2.5	
PCB-036	<29	33.1		PCB-146	180	163	9.9
PCB-039	<25	<29		PCB-161	<3.2	<2.3	
PCB-038	<24	<28		PCB-153/168	1020	955	6.6
PCB-035	<26	<30		PCB-141	166	146	12.8
PCB-037	820	741	10.1	PCB-130	<68	65.5	
PCB-054	<2.7	<3.0		PCB-137/164	165	147	11.5
PCB-050/053	286	250	13.4	PCB-129/138/163	1210	1120	7.7
PCB-045/051	335	296	12.4	PCB-160	<2.7	<2.0	
PCB-046	110	102	7.5	PCB-158	70.9	62	13.4
PCB-052	3020	2670	12.3	PCB-128/166	132	114	14.6
PCB-073	<3.1	<5.1		PCB-159	10.9	8.41	25.8
PCB-043	<92	<80		PCB-162	2.86	<2.0	
PCB-049/069	1410	1250	12.0	PCB-167	31.2	25.3	20.9
PCB-048	372	319	15.3	PCB-156/157	74.5	61.5	19.1
PCB-044/047/065	2290	2090	9.1	PCB-169	<3.5	<3.6	
PCB-059/062/075	207	182	12.9	PCB-188	<0.52	<0.64	
PCB-042	567	505	11.6	PCB-179	120	113	6.0
PCB-040/041/071	866	777	10.8	PCB-184	0.531	<0.64	
PCB-064	1010	893	12.3	PCB-176	26.8	28.2	-5.1
PCB-072	<29	<37		PCB-186	<0.54	<0.69	
PCB-068	<24	<30		PCB-178	67.6	63.4	6.4
PCB-057	<30	<37		PCB-175	10.2	9.45	7.6
PCB-058	<30	<38		PCB-187	394	351	11.5
PCB-067	<23	<29		PCB-182	<0.68	<0.86	
PCB-063	<37	<34		PCB-183	162	141	13.9
PCB-061/070/074/076	2640	2300	13.8	PCB-185	<0.73	<0.93	
PCB-066	2730	2420	12.0	PCB-174	315	279	12.1
PCB-055	<27	<34		PCB-177	171	152	11.8
PCB-056	734	<38		PCB-181	1.93	<0.89	
PCB-060	273	218	22.4	PCB-171/173	75.6	68.7	9.6
PCB-080	<26	<33		PCB-172	47.6	41.8	13.0
PCB-079	<28	<36		PCB-192	<0.57	<0.73	
PCB-078	<30	<38		PCB-180/193	648	544	17.4
PCB-081	<37	<50		PCB-191	14	12.1	14.6
PCB-077	137	123	10.8	PCB-170	274	229	17.9
PCB-104	<1.7	<2.0		PCB-190	54.1	46.8	14.5
PCB-096	<7.8	8.01		PCB-189	10.2	9.69	5.1
PCB-103	12.6	<9.5		PCB-202	42.1	33	24.2
PCB-094	<6.1	<6.4		PCB-201	23.4	20.7	12.2
PCB-095	901	776	14.9	PCB-204	<0.38	<0.62	
PCB-093/098/100/102	<42	43.4		PCB-197	<6.4	6.05	
PCB-088/091	178	151	16.4	PCB-200	19.5	17.4	11.4
PCB-084	273	229	17.5	PCB-198/199	224	190	16.4
PCB-089	<11	<9.1		PCB-196	83.3	67.8	20.5
PCB-121	<3.7	<4.3		PCB-203	120	99.9	18.3
PCB-092	209	179	15.5	PCB-195	55	48.6	12.4
PCB-090/101/113	1190	996	17.7	PCB-194	153	121	23.4
PCB-083/099	876	733	17.8	PCB-205	<7.7	7.63	
PCB-112	<4.0	<4.5		PCB-208	32.8	28.1	15.4
PCB-086/087/097/109/119/125	683	567	18.6	PCB-207	13.1	<2.7	
PCB-085/110/115/116/117	1840	1420	25.8	PCB-206	116	<86	
PCB-082	168	<130		PCB-209	81.5	60.2	30.1

Mean = 13.4%; Range = 0.5-30.1%

Table A8. Relative percent difference (RPD) for 2015 sample duplicates – PCB congener homologues and totals.

Sample Name	**TC01**	**Duplicate of TC01**	**RPD**
Homologue Group Totals	pg/g	pg/g	**%**
Total MonoCB	80.7	68.5	16.4
Total DiCB	1630	733	75.9
Total TriCB	10700	10000	6.8
Total TetraCB	17100	14500	16.5
Total PentaCB	7880	6510	19.0
Total HexaCB	4730	4230	11.2
Total HeptaCB	2390	2090	13.4
Total OctaCB	734	612	18.1
Total NonaCB	162	114	34.8
DecaCB	81.5	60.2	30.1
Total PCB Congeners (ng/g)	**45.0**	**38.2**	16.3
Mean = 23.5%; Range = 6.8-75.9%			

Table A9. Recovery of metals, metal oxides, and nutrients in reference materials/standards run concurrently with 2015 sediment samples.

PARAMETERS	QC Sample Recovery Calculation			
	Raw Data (µg/g)		QC Sample Recovery	
SC0063618 (03-Dec-15)	QC Result	Reference Value	% Recovery	Control Limits
Aluminum	11100	12163	91	70 - 130
Antimony	10.1	9.9	102	70 - 130
Arsenic	20.9	20.7	101	70 - 130
Barium	449	426	105	70 - 130
Beryllium	0.4	0.373	108	70 - 130
Cadmium	2.5	3.17	79	70 - 130
Calcium	51300	50265	102	70 - 130
Chromium	80	77.6	103	70 - 130
Cobalt	14	12.9	111	70 - 130
Copper	395	403	98	70 - 130
Iron	87000	72000	121	70 - 130
Lead	730	764	96	70 - 130
Magnesium	8730	9690	90	70 - 130
Manganese	710	737	96	70 - 130
Molybdenum	6	5.7	109	70 - 130
Nickel	58	59.2	98	70 - 130
Phosphorus	1520	1552	98	70 - 130
Potassium	1810	2232	81	70 - 130
Silver	0.8	0.88	89	70 - 130
Sodium	640	650	98	70 - 130
Strontium	119	114	104	70 - 130
Tin	349	340	103	70 - 130
Titanium	469	530	88	70 - 130
Vanadium	24	27.2	89	70 - 130
Zinc	1070	1114	96	70 - 130
SC0063618 (03-Dec-15)				
Mercury	0.423	0.410	103	70 - 130
LKSD-2 (08-Dec-15)				
Aluminum (Al2O3)	10.5	12.3	86	75 - 125
Calcium (CaO)	1.96	2.2	89	75 - 125
Iron (Fe2O3)	5.73	6.2	92	75 - 125
Magnesium (MgO)	1.54	1.7	91	75 - 125
Manganese (MnO)	0.248	0.3	83	60 - 140
Potasium (K20)	2.4	2.6	91	70 - 130
Silica (SiO2)	55.7	58.9	95	75 - 125
Titanium (TiO2)	0.6	0.6	97	75 - 125
LOI @1000°C	13.0	13.6	96	75 - 125
CRM-542 (01-Dec-15)				
Total Kjeldahl Nitrogen	1985	1493	133	50 - 150
Phosphorus-Total	1192	1041	115	44 - 156

Range : 79-133%; Mean : 98%

Table A10. Recovery PCB congeners in Laboratory Control Samples run concurrently with 2015 sediment samples.

Sample Name	Laboratory Control Sample Recovery (%)
Target Analytes	
PCB-001	111
PCB-003	103
PCB-004	103
PCB-015	99
PCB-019	113
PCB-037	88
PCB-054	106
PCB-081	99
PCB-077	98
PCB-104	98
PCB-123	107
PCB-118	109
PCB-114	108
PCB-105	105
PCB-126	103
PCB-155	101
PCB-167	99
PCB-156/157	99
PCB-169	97
PCB-188	103
PCB-189	110
PCB-202	107
PCB-205	109
PCB-208	111
PCB-206	120
PCB-209	114
Mean = 104.6%; Range = 88-120%	

Table A11. Recovery of PCB congeners in Laboratory Control Samples, run concurrently with 2015 tissue samples.

Sample Name	Laboratory Control	Laboratory Control
ALS Sample ID	WG2204784-2	WG2204787-2
Target Analytes	**% Rec**	**% Rec**
PCB-001	119	117
PCB-003	110	112
PCB-004	104	101
PCB-015	106	106
PCB-019	116	108
PCB-037	94	96
PCB-054	113	103
PCB-081	108	108
PCB-077	104	104
PCB-104	101	98
PCB-123	115	115
PCB-118	116	115
PCB-114	116	115
PCB-105	112	111
PCB-126	111	111
PCB-155	104	102
PCB-167	106	104
PCB-156/157	106	103
PCB-169	108	103
PCB-188	106	102
PCB-189	118	118
PCB-202	110	104
PCB-205	114	114
PCB-208	116	112
PCB-206	128	126
PCB-209	120	118
Mean: 109.8%; Range: 94-128%		

Table A12. Recovery of PAHs and total PCBs in matrix spikes and spiked blanks run concurrently with 2015 sediment samples.

QC Type	Parameter	% Recovery	QC Limits		QC Type	Parameter	% Recovery	QC Limits
Matrix Spike	Acenaphthene	82	50 - 130		Spiked Blank	Acenaphthene	85	50 - 130
	Acenaphthylene	84	50 - 130			Acenaphthylene	86	50 - 130
	Anthracene	83	50 - 130			Anthracene	87	50 - 130
	Benzo(a)anthracene	84	50 - 130			Benzo(a)anthracene	86	50 - 130
	Benzo(a)pyrene	82	50 - 130			Benzo(a)pyrene	83	50 - 130
	Benzo(b/j)fluoranthene	83	50 - 130			Benzo(b/j)fluoranthene	86	50 - 130
	Benzo(g,h,i)perylene	73	50 - 130			Benzo(g,h,i)perylene	74	50 - 130
	Benzo(k)fluoranthene	79	50 - 130			Benzo(k)fluoranthene	82	50 - 130
	Chrysene	82	50 - 130			Chrysene	85	50 - 130
	Dibenz(a,h)anthracene	72	50 - 130			Dibenz(a,h)anthracene	71	50 - 130
	Fluoranthene	85	50 - 130			Fluoranthene	87	50 - 130
	Fluorene	89	50 - 130			Fluorene	91	50 - 130
	Indeno(1,2,3-cd)pyrene	82	50 - 130			Indeno(1,2,3-cd)pyrene	82	50 - 130
	1-Methylnaphthalene	82	50 - 130			1-Methylnaphthalene	83	50 - 130
	2-Methylnaphthalene	78	50 - 130			2-Methylnaphthalene	81	50 - 130
	Naphthalene	75	50 - 130			Naphthalene	76	50 - 130
	Phenanthrene	80	50 - 130			Phenanthrene	84	50 - 130
	Pyrene	83	50 - 130			Pyrene	84	50 - 130
	Aroclor 1260	84	60 - 130			Aroclor 1260	96	60 - 130
	Total PCB	84	60 - 130			Total PCB	96	60 - 130
	Mean	81.3				Mean	84.3	
	Range	72-89%				Range	71-96%	

Table A13. Summary of spiked blank and laboratory control sample recoveries, duplicate spikes and method blanks for BTEX and petroleum hydrocarbon sediment samples (National Laboratory for Environmental Testing).

	LCS1 % recovery	LCS1 - dup % recovery	Blank spike 1 % recovery	Blank spike 1-dup % recovery	Blank Spike RPD
Fraction 1 (C6-C10)	N/A	N/A	N/A	N/A	N/A
Benzene	101	102	102	102	0
Toluene	97.5	100	101	102	1.23
Ethylbenzene	101	98.3	98.9	101	2.47
m,p-Xylenes	97.9	99.2	97.8	98.4	0.639
o-Xylene	98.7	98.7	98.7	108	8.59

NLET	F1 (ug/g)	F1 Spike % Recovery	F2 (ug/g)	F2 Spike % Recovery	F3 (ug/g)	F3 Spike % Recovery	F4 (ug/g)	F4 Spike % Recovery	F4G (ug/g)	F4G Spike % Recovery
METHOD BLK	7.89		1.63		1.44		1.18		N.D.	
SPK BLK		99	5060	101	5060	101	5100	97.8	95.9	102

N/A = not applicable; N.D. = not detected

Table A14. Recovery of surrogates of PAHs and total PCBs in matrix and blank spikes.

QC Type	Parameter	% Recovery	QC Limits		QC Type	Parameter	% Recovery	QC Limits
Matrix Spike	D10-Anthracene	90	50 - 130		Spiked Blank	D10-Anthracene	93	50 - 130
	D14-Terphenyl (FS)	74	50 - 130			D14-Terphenyl (FS)	76	50 - 130
	D8-Acenaphthylene	82	50 - 130			D8-Acenaphthylene	85	50 - 130
	Decachlorobiphenyl	95	60 - 130			Decachlorobiphenyl	102	60 - 130
	Mean	85.3				Mean	89.0	
	Range	74-95 %				Range	76-102 %	

Table A15. Recovery of surrogates of PAHs and total PCBs in routine sediment samples, 2015.

	TC01	BEC02	UC01	LC01	LC03	LC08	LC1200	LC1201	LC1202	LC16	LC18	LC22	LC38
Surrogate Recovery (%)													
Polyaromatic Hydrocarbons													
D10-Anthracene	93	102	95	98	103	99	94	92	65	99	103	98	100
D14-Terphenyl (FS)	74	82	77	76	91	81	74	74	56	73	75	77	75
D8-Acenaphthylene	90	105	94	96	85	95	98	99	68	98	100	98	99
Mean= 88.5%; Range = 56-105%													
Surrogate Recovery (%)													
Polychloreinated biphenyls													
Decachlorobiphenyl	95	91	80	94	92	95	82	81	93	77	83	85	108
Mean= 88.9%; Range =77-108%													

Table A16. Method blank values (PAHs, total PCBs) for samples run concurrently with 2015 sediment samples.

QC Type	Parameter	Value
Method Blank	Acenaphthene	ND, RDL=0.0050
	Acenaphthylene	ND, RDL=0.0050
	Anthracene	ND, RDL=0.0050
	Benzo(a)anthracene	ND, RDL=0.0050
	Benzo(a)pyrene	ND, RDL=0.0050
	Benzo(b/j)fluoranthene	ND, RDL=0.0050
	Benzo(g,h,i)perylene	ND, RDL=0.0050
	Benzo(k)fluoranthene	ND, RDL=0.0050
	Chrysene	ND, RDL=0.0050
	Dibenz(a,h)anthracene	ND, RDL=0.0050
	Fluoranthene	ND, RDL=0.0050
	Fluorene	ND, RDL=0.0050
	Indeno(1,2,3-cd)pyrene	ND, RDL=0.0050
	1-Methylnaphthalene	ND, RDL=0.0050
	2-Methylnaphthalene	ND, RDL=0.0050
	Naphthalene	ND, RDL=0.0050
	Phenanthrene	ND, RDL=0.0050
	Pyrene	ND, RDL=0.0050
	Aroclor 1016	ND, RDL=0.010
	Aroclor 1221	ND, RDL=0.010
	Aroclor 1232	ND, RDL=0.010
	Aroclor 1242	ND, RDL=0.010
	Aroclor 1248	ND, RDL=0.010
	Aroclor 1254	ND, RDL=0.010
	Aroclor 1260	ND, RDL=0.010
	Aroclor 1262	ND, RDL=0.010
	Aroclor 1268	ND, RDL=0.010
	Total PCB	ND, RDL=0.010

Table A17. Method blank values (PCB congeners) for samples run concurrently with 2015 sediment samples.

Sample Name	Method Blank	Sample Name	Method Blank
Target Analytes	pg/g		pg/g
PCB-001	<0.39	PCB-111	<0.069
PCB-002	<0.39	PCB-120	<0.068
PCB-003	<0.33	PCB-108/124	<0.13
PCB-004	<12	PCB-107	<0.14
PCB-010	<10	PCB-123	<0.13
PCB-009	<11	PCB-106	<0.14
PCB-007	<9.7	PCB-118	<1.1
PCB-006	<9.3	PCB-122	<0.14
PCB-005	<12	PCB-114	<0.13
PCB-008	<8.5	PCB-105	<0.70
PCB-014	<1.3	PCB-127	<0.12
PCB-011	<6.1	PCB-126	<0.16
PCB-012/013	<1.4	PCB-155	<0.027
PCB-015	<1.7	PCB-152	<0.030
PCB-019	<0.76	PCB-150	<0.022
PCB-018/030	3	PCB-136	<0.11
PCB-017	1.28	PCB-145	<0.028
PCB-027	<0.35	PCB-148	<0.037
PCB-024	<0.34	PCB-135/151	<0.18
PCB-016	<1.1	PCB-154	<0.045
PCB-032	0.933	PCB-144	<0.038
PCB-034	<0.38	PCB-147/149	0.652
PCB-023	<0.32	PCB-134/143	<0.094
PCB-026/029	0.6	PCB-139/140	<0.081
PCB-025	<0.29	PCB-131	<0.095
PCB-031	3.75	PCB-142	<0.098
PCB-020/028	<5.1	PCB-132	0.313
PCB-021/033	<2.2	PCB-133	<0.096
PCB-022	1.48	PCB-165	<0.072
PCB-036	<0.35	PCB-146	<0.079
PCB-039	<0.39	PCB-161	<0.064
PCB-038	<0.37	PCB-153/168	0.504
PCB-035	<0.44	PCB-141	<0.17
PCB-037	<0.71	PCB-130	<0.096
PCB-054	<0.089	PCB-137/164	<0.13
PCB-050/053	0.533	PCB-129/138/163	0.851
PCB-045/051	0.867	PCB-160	<0.054
PCB-046	<0.25	PCB-158	<0.084
PCB-052	4.03	PCB-128/166	<0.11
PCB-073	2.71	PCB-159	<0.062
PCB-043	<0.12	PCB-162	<0.060
PCB-049/069	<1.7	PCB-167	0.0553
PCB-048	<0.86	PCB-156/157	<0.070
PCB-044/047/065	4.17	PCB-169	<0.063
PCB-059/062/075	<0.28	PCB-188	<0.042
PCB-042	0.953	PCB-179	<0.046
PCB-040/041/071	1.99	PCB-184	<0.039
PCB-064	<1.4	PCB-176	<0.042
PCB-072	<0.29	PCB-186	<0.043
PCB-068	<0.24	PCB-178	<0.061
PCB-057	<0.29	PCB-175	<0.058
PCB-058	<0.29	PCB-187	0.159
PCB-067	<0.23	PCB-182	<0.054
PCB-063	<0.27	PCB-183	<0.055
PCB-061/070/074/076	4.51	PCB-185	<0.059
PCB-066	2.98	PCB-174	0.164
PCB-055	<0.28	PCB-177	<0.063
PCB-056	<1.0	PCB-181	<0.057
PCB-060	0.944	PCB-171/173	<0.063
PCB-080	<0.27	PCB-172	<0.061
PCB-079	<0.28	PCB-192	<0.048
PCB-078	<0.31	PCB-180/193	<0.25
PCB-081	<0.30	PCB-191	<0.043
PCB-077	<0.32	PCB-170	<0.095
PCB-104	<0.050	PCB-190	<0.046
PCB-096	<0.042	PCB-189	<0.058
PCB-103	<0.084	PCB-202	<0.025
PCB-094	<0.097	PCB-201	<0.027
PCB-095	1.28	PCB-204	<0.024
PCB-093/098/100/102	<0.12	PCB-197	<0.025
PCB-088/091	0.334	PCB-200	<0.026
PCB-084	0.594	PCB-198/199	<0.083
PCB-089	<0.10	PCB-196	0.058
PCB-121	<0.064	PCB-203	<0.050
PCB-092	0.223	PCB-195	<0.063
PCB-090/101/113	1.52	PCB-194	<0.19
PCB-083/099	0.989	PCB-205	<0.054
PCB-112	<0.069	PCB-208	<0.13
PCB-086/087/097/109/119/1	1.4	PCB-207	<0.13
PCB-085/110/115/116/117	5.76	PCB-206	<0.25
PCB-082	<0.32	PCB-209	0.56

Table A18. Method blank values (PCB congeners) run concurrently with 2015 tissue samples.

Sample Name	Method Blank	Method Blank	Sample Name	Method Blank	Method Blank
ALS Sample ID	WG2204784-	WG2204787-	ALS Sample ID	WG2204784-	WG2204787-
Target Analytes	**pg/g**	**pg/g**	**Target Analyte**	**pg/g**	**pg/g**
PCB-001	<1.0	<0.76	PCB-111	<0.20	<0.15
PCB-002	<1.3	<1.6	PCB-120	<0.19	<0.14
PCB-003	<2.1	<2.2	PCB-108/124	<0.50	<0.20
PCB-004	<2.7	<4.7	PCB-107	<0.27	<0.56
PCB-010	<0.74	<2.3	PCB-123	<0.31	<0.23
PCB-009	<0.83	<2.4	PCB-106	<0.27	<0.21
PCB-007	2.45	<36	PCB-118	6.93	8.79
PCB-006	<0.71	<2.2	PCB-122	<0.29	<0.27
PCB-005	<0.91	<2.6	PCB-114	<0.30	<0.38
PCB-008	14	17.4	PCB-105	3.92	5.06
PCB-014	<0.84	<1.7	PCB-127	<0.19	<0.19
PCB-011	57.4	63	PCB-126	<0.29	<0.23
PCB-012/013	<0.89	<1.7	PCB-155	<0.21	0.25
PCB-015	8.76	6.6	PCB-152	<0.16	<0.11
PCB-019	<0.88	2.04	PCB-150	<0.13	<0.085
PCB-018/030	<8.9	9.45	PCB-136	1.05	0.97
PCB-017	6.24	5.18	PCB-145	<0.15	<0.099
PCB-027	<0.48	<0.67	PCB-148	<0.19	<0.13
PCB-024	<0.27	<0.24	PCB-135/151	<2.3	2.64
PCB-016	<4.5	5.07	PCB-154	<0.15	<0.20
PCB-032	<3.6	3.88	PCB-144	<0.19	0.49
PCB-034	<0.45	<0.39	PCB-147/149	6.11	6.37
PCB-023	<0.40	<0.36	PCB-134/143	<0.53	0.63
PCB-026/029	<3.5	3.69	PCB-139/140	<0.30	<0.25
PCB-025	1.08	1.35	PCB-131	<0.32	<0.14
PCB-031	20.8	23.3	PCB-142	<0.36	<0.15
PCB-020/028	30.8	32.7	PCB-132	<2.5	2.93
PCB-021/033	13.3	15.3	PCB-133	<0.32	<0.14
PCB-022	11.2	12.3	PCB-165	<0.24	<0.11
PCB-036	<0.39	<0.34	PCB-146	0.7	0.88
PCB-039	<0.44	<0.39	PCB-161	<0.21	<0.10
PCB-038	<0.42	<0.37	PCB-153/168	4.94	6.13
PCB-035	0.96	1.25	PCB-141	<1.7	1.46
PCB-037	13	14.6	PCB-130	<0.27	<0.42
PCB-054	<0.28	<0.18	PCB-137/164	<0.33	<0.76
PCB-050/053	1.34	<2.0	CB-129/138/163	6.91	9.46
PCB-045/051	<3.2	4.05	PCB-160	<0.16	<0.094
PCB-046	<0.87	<1.2	PCB-158	0.78	<0.79
PCB-052	12.8	18.6	PCB-128/166	1.27	1.31
PCB-073	<0.17	<0.15	PCB-159	<0.18	<0.098
PCB-043	0.73	<0.95	PCB-162	<0.18	<0.097
PCB-049/069	6.35	10.4	PCB-167	0.33	0.36
PCB-048	2.7	4.71	PCB-156/157	0.98	1.04
PCB-044/047/065	14.1	21.3	PCB-169	<0.17	<0.10
PCB-059/062/075	<1.3	<2.0	PCB-188	<0.20	<0.078
PCB-042	4.17	6.21	PCB-179	<0.78	0.76
PCB-040/041/071	8.94	12.7	PCB-184	<0.16	<0.075
PCB-064	6.65	10.9	PCB-176	<0.18	<0.20
PCB-072	<0.25	<0.19	PCB-186	<0.17	<0.087
PCB-068	<0.35	<0.37	PCB-178	<0.22	<0.28
PCB-057	<0.25	<0.20	PCB-175	<0.21	<0.11
PCB-058	0.26	<0.37	PCB-187	<1.4	1.7
PCB-067	<0.34	<0.75	PCB-182	<0.19	<0.10
PCB-063	<0.33	1.16	PCB-183	0.83	<0.82
PCB-061/070/074/076	22.6	35.8	PCB-185	<0.21	<0.28
PCB-066	14.1	24.2	PCB-174	<1.5	1.42
PCB-055	<0.68	1.14	PCB-177	<0.97	0.97
PCB-056	7.11	11.3	PCB-181	<0.19	<0.11
PCB-060	6.28	8.88	PCB-171/173	<0.21	<0.72
PCB-080	<0.22	<0.27	PCB-172	<0.20	<0.29
PCB-079	<0.24	<0.16	PCB-192	<0.15	<0.087
PCB-078	<0.26	<0.18	PCB-180/193	2.33	2.34
PCB-081	<0.28	<0.18	PCB-191	<0.13	<0.081
PCB-077	2.23	2.9	PCB-170	1.44	1.14
PCB-104	<0.20	<0.14	PCB-190	<0.13	<0.13
PCB-096	<0.20	<0.14	PCB-189	<0.12	<0.11
PCB-103	<0.27	<0.22	PCB-202	<0.15	<0.15
PCB-094	<0.30	<0.24	PCB-201	<0.12	<0.098
PCB-095	6.03	<6.7	PCB-204	<0.11	<0.086
PCB-093/098/100/102	<0.27	<0.22	PCB-197	<0.11	<0.090
PCB-088/091	<1.2	1.83	PCB-200	<0.11	<0.094
PCB-084	2.69	2.93	PCB-198/199	<0.40	<0.46
PCB-089	<0.32	<0.24	PCB-196	<0.15	0.31
PCB-121	<0.19	<0.15	PCB-203	<0.13	<0.28
PCB-092	<1.0	<1.7	PCB-195	<0.17	<0.18
PCB-090/101/113	<7.4	9.5	PCB-194	<0.16	0.24
PCB-083/099	<4.1	5.67	PCB-205	<0.14	<0.10
PCB-112	<0.22	<0.16	PCB-208	<0.67	<0.19
B-086/087/097/109/119/125	7.23	13.2	PCB-207	<0.50	<0.17
PCB-085/110/115/116/117	12.2	<13	PCB-206	<0.70	<0.31
PCB-082	<1.3	1.82	PCB-209	1.42	1.34

Table A19. Sorting efficiencies (SE) (%) for 2015 Lyons Creek East benthic invertebrate samples.

Sample No.	Original Count	QA audit count	Missed	Comments	% SE
LC03iv	55	55	0		1- (0/55) * 100 = 100
LC1200iv	64	78	14	1 worm, 6 ceratopogonids and 7 chironomids	1- (14/78) * 100 = 82.05
LC22iii	14	14	0		1- (0/14) * 100 = 100
LC1201v	56	58	2	2 chironomids	1- (2/58) * 100 = 96.55
LC1202iii	59	58	0		1- (0/59) * 100 = 100
				Mean	**95.72%**

Table A20. Taxonomy identification errors (IE) (%) and corrective action taken for 2015 Lyons Creek East samples.

TAXA	BIOTAX counts	Logan counts	Taxa resolution	Counts different	misdet. taxon	Comments
Site: LC03 iv	**Location: Lyons Cr.**					
Quistadrilus multisetosus	2	2				
Tubificinae imm. w/out hairs	43	43				
Coenagrionidae	1	1				early instar
Dubiraphia	1	1				
Bezzia	1	1				IDed as Bezzia/Palpomyia
Cricotopus	1	1				
Paratanytarsus	1	1				
Gyraulus	3	3				one broken
Pisidium	1	1				
Pisidium nitidum	1	1				
TOTAL=	55	55	ID error 0% - PASS			

TAXA	BIOTAX counts	Logan counts	Taxa resolution	Counts different	misdet. taxon	Comments
Site: LC1200 iv	**Location: Lyons Cr.**					
Aulodrilus pigueti	1	1				
Tubificinae imm. w/out hairs	8	8				
Gammarus	1	1				
Hyalella azteca	1	1				cmplx
Limnesia	1	1				
Piona	1	1				
Caenis	2	2				early instar
Hydrophilidae	0	1				
Orthotrichia	1	0	x			early instar, left at family Hydrophilidae
Bezzia	1	1				IDed as Bezzia/Palpomyia
Culicoides	13	11		x		
Mallochohelea	2	3		x		
Clinotanypus pinguis	1	1				
Procladius	12	12				
Chironominae	0	1				
Cladopelma	1	0	x			
Cryptochironomus	3	3				
Cryptotendipes	1	1				
Paralauterborniella nigrohaltera	1	1				
Polypedilum simulans	10	10	x			changed to P. halterale grp
Tanytarsus	2	2				
Pisidium nitidum	1	1				
TOTAL=	64	63	ID error 0% - PASS			

Table A20. Continued.

TAXA	BIOTAX counts	Logan counts	Taxa resolution	Counts different	misdet. taxon	Comments
Site: LC1201 v	**Location: Lyons Cr.**					
Aulodrilus pigueti	1	1				
Limnodrilus hoffmeisteri	1	1				
Tubificinae imm. with hairs	1	1				
Tubificinae imm. w/out hairs	6	6				
Caenis	2	2				tiny
Caenis punctata	1	1				chkd hindleg & S9
Corixidae	1	1				nymph
Oecetis	1	1				inconspicua grp sp. A Floyd
Culicoides	14	11		x		
Probezzia	5	5				
Sphaeromias	2	1		x		
Clinotanypus pinguis	1	1				
Procladius	6	6				
Chironominae	0	1				
Cladopelma	1	0	x			early instar, left at subfam. Chironominae
Cryptochironomus	1	1				
Cryptotendipes	1	1				
Dicrotendipes	5	4		x		early instar;
Polypedilum simulans	4	3	x	x		changed to P. halterale grp; on slide
Tanytarsus	2	0		x		missing spec.
Pisidium nitidum	1	1				
TOTAL=	57	49	ID error 0% - PASS			

TAXA	BIOTAX counts	Logan counts	Taxa resolution	Counts different	misdet. taxon	Comments
Site: LC1202 iii	**Location: Lyons Cr.**					
Aulodrilus pigueti	1	1				slide-mounted
Tubificinae imm. w/out hairs	4	4				slide-mounted
Hydrodroma	1	1				
Culicoides	19	19				
Probezzia	6	6				
Sphaeromias	1	1				
Clinotanypus pinguis	1	1				
Procladius	7	7				
Cladopelma	1	1				
Cryptochironomus	9	9				
Dirotendipes	2	1		x		early instar
Paralauterborniella nigrohaltera	2	2				
Polypedilum simulans	4	3	x	x		changed to P. halterale grp
Tanytarsus	1	1				
Pisidium	1	1				
TOTAL=	60	58	ID error 0% - PASS			

Table A20. Continued.

TAXA	BIOTAX counts	Logan counts	Taxa resolution	Counts different	misdet. taxon	Comments
Site: LC22 iii	**Location: Lyons Cr.**					
Aulodrilus pigueti	1	1				
Tubificinae imm. with hairs	1	1				
Tubificinae imm. w/out hairs	1	1				
Limnesia	1	1				
Probezzia	1	1				
Procladius	1	1				
Cryptochironomus	3	3				
Paralauterborniella nigrohaltera	1	1				
Cladotanytarsus	1	1				
Tanytarsus	2	2				
Zavreliella marmorata	1	1				
TOTAL=	14	14	ID error 0% - PASS			

Table A21. Toxicological response in laboratory control sediment (Long Point, Lake Erie) run concurrently with 2015 Lyons Creek East test samples.

Test set	Sites	*H. azteca*		*C. riparius*		*Hexagenia*		*T. tubifex*				Met criteria? (Y/N)
		surv	growth	surv	growth	surv	growth	surv	No. cocs/ind.	% cocs hatched	No. young/ind	
1	TC01, BEC02, LC01	89.3	0.286	86.7	0.380	100	5.01	100	12.5	61.6	39.0	Y
2	LC22, LC18. LC16	92.0	0.365	96.0	0.384	96	4.65	100	12.3	61.6	37.9	Y
3	LC38	93.3	0.356	96.0	0.383	100	5.63	100	11.7	58.4	36.9	Y
4	LC12	93.3	0.352	98.7	0.405	100	5.33	100	12.5	62.8	37.6	Y
5	LC08	93.3	0.386	98.7	0.496	100	5.28	100	12.2	62.4	39.2	Y
6	LC03	93.3	0.432	96.0	0.496	100	5.58	100	11.9	59.1	35.9	Y

APPENDIX B

Supplemental information

Zones in Lyons Creek East

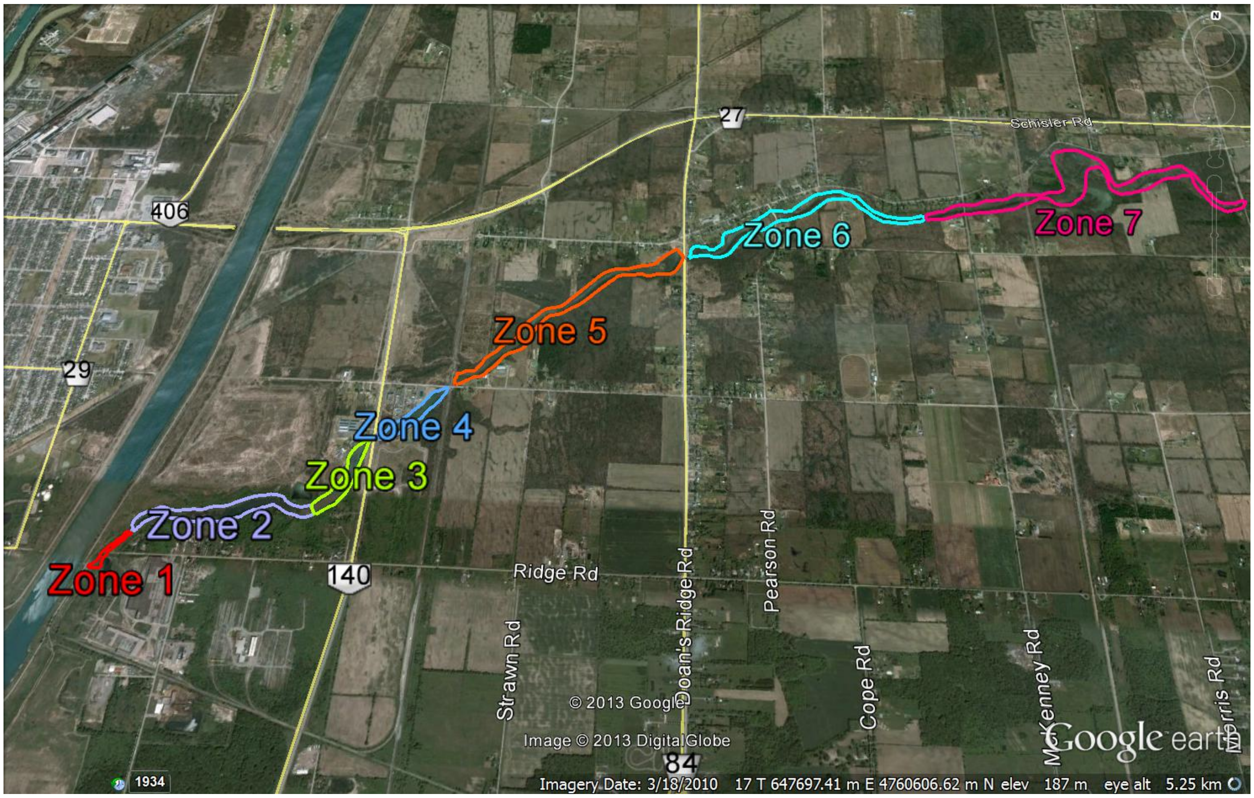


Figure B1. Identification of zones in Lyons Creek East (from MOECC and ECCC 2016)

Particle size

LCE sediments consisted mainly of silt + clay (fines) which ranged from 81.8 to 97.6% (Table B1, Figure B2). Sand content was highest at LC38 (farthest downstream) at 18.2%, while remaining LCE sites had ≤ 12.7%. There was a minimal amount of gravel present in the upper creek LCE sites (LC01 and LC03) (≤ 1.9%) (Figure B2). Comparatively, Tee Creek was physically the most similar to LCE, with fines representing 92% while Beaver and Usshers creeks were sandier (32-46% sand) with less fines (47-68%) (Figure B2; Table B1). Usshers Creek also had 6.6% gravel present. The reference creeks were determined to be appropriate reference locations for LCE based on proximity, geomorphology, and physical and chemical characteristics in the 2002/2003 study (Milani et al. 2013); however, any observed differences between LCE and reference creek benthic communities, particularly Usshers Creek, will consider particle size.

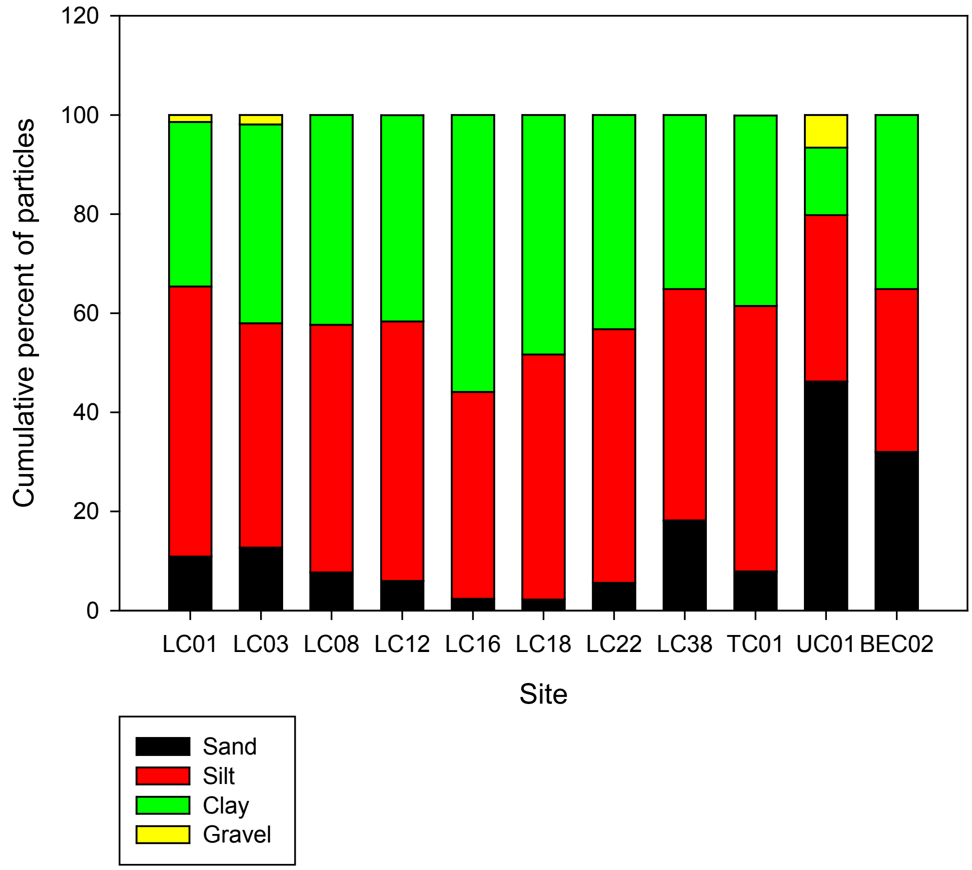


Figure B2. Particle size distribution in 2015 Lyons Creek East and reference creeks (TC = Tee Creek, UC = Usshers Creek, BEC = Beaver Creek

Table B1. Particle size distribution for 2015 Lyons Creek East and Reference creeks.

Zone	Site	Year	% Clay	% Gravel	% Sand	% Silt
1	LC01	2015	33.2	1.4	10.9	54.5
1	LC03	2015	40.1	1.9	12.7	45.3
2	LC08	2015	42.3	0	7.7	50
2	LC12	2015	41.60	0.0	6.00	52.37
3	LC16	2015	55.9	0	2.4	41.7
4	LC18	2015	48.3	0	2.2	49.5
5	LC22	2015	43.2	0	5.6	51.2
d/s	LC38	2015	35.1	0	18.2	46.7
Ref	TC40	2015	38.4	0	7.9	53.6
Ref	UC01	2015	13.6	6.6	46.2	33.6
Ref	BEC02	2015	35.1	0	32	32.9

Overlying Water Properties

Conditions of overlying water 0.5 m above the sediment were generally similar in the upper creek from LC01 to LC16 (Highway 140) suggesting some homogeneity in water mass across these sampling areas (Table B2). Downstream of Highway 140, concentrations of TKN and TP increased and were highest at LC38, the site farthest downstream (Table B2); conductivity and NO_3+NO_2 were also highest at LC38. Lower dissolved oxygen was observed at or downstream of Highway 140 (5.1-6.6 mg/L) compared to upstream (≥ 7 mg/L) and pH (7.6-8.5) and alkalinity (88-101 mg/L) were similar throughout the creek (Table B2). Two of the three reference creeks (Tee and Usshers Creek) were fairly similar in overlying water characteristics to LCE. Beaver Creek (BEC02) was the most dissimilar to LCE with higher conductivity, NO_3+NO_2, TKN and TP - this was also found in 2010 (Milani and Grapentine 2014).

Trends in overlying water conditions from 2002 to 2015 are shown in Figures B2 and B3. Dissolved oxygen showed both increases and decreases since 2010 but in 2015 were above the provincial water quality objective (PWQO) lower range of 5 mg/L for the protection of warm water biota. Generally warmer temperatures and lower dissolved oxygen were evident (with some exceptions) from 2010, likely a reflection on sampling time (early to late October in 2002/2003 and early/mid-September in 2010 and 2015). Alkalinity was ≥ 86 mg/L and was fairly stable across sampling periods with the exception of reference creek site BEC02 which showed a spike and reverse from 2002-2015 and pH was stable since 2010 and was neutral to alkaline throughout the sampling period (≥ 7.0) (Figure B2). Concentrations of the overlying water nutrients at LCE sites were within or below the range of those observed for the neighbouring three reference creeks (Figure B3). TKN, and nitrate + nitrite concentrations showed similar trends with most variability evident in the reference creeks; LCE sites had mostly stable concentrations since 2002 (Figure B3). Total ammonia was generally stable or declined overall since 2002 or 2010 and total P was generally stable since 2002 or 2010 in LCE (Figure B3). Concentrations of TP were mostly below the PWQO of 0.02 mg/L throughout the time period except for the reference creeks and the LCE site farthest downstream (LC38) (Figure B3).

Table B2. Characteristics of sampling site overlying water (0.5 m from bottom) for 2015 Lyons Creek East and reference creek sites.

Site	Depth	Temp	Dissolved O_2	Alkalinity	Conductivity	pH	NH_3	NO_3/NO_2	Total Kjeldahl Nitrogen	Total Phosphorus
Units	m	°C	mg/L	mg/L	µS/cm	-	mg/L	mg/L	mg/L	mg/L
LC01	1.40	20.2	7.6	93	276	8.2	0.026	0.082	0.246	0.013
LC03	0.30	20.2	7.7	96	279	8.3	0.028	0.086	0.269	0.012
LC08	0.06	21.5	10.0	91	266	8.5	0.014	0.071	0.269	0.016
LC12[a]	0.12	18.16	7.0	97	280	7.8	0.016	0.047	0.264	0.014
LC16	0.37	21.4	5.9	101	285	7.8	0.019	0.016	0.275	0.017
LC18	0.20	20.9	5.7	93	281	7.8	0.020	0.015	0.328	0.028
LC22	0.07	20.6	5.1	101	305	7.7	0.015	0.014	0.309	0.032
LC38	0.53	18.9	6.6	88	445	7.6	0.029	0.518	0.657	0.088
TC01	0.70	15.1	5.4	86	425	7.6	0.063	0.404	0.729	0.132
UC01	0.56	19.8	6.7	93	320	8.0	0.020	0.112	0.350	0.024
BEC02	0.27	18.3	5.5	101	608	7.5	0.053	2.590	1.320	0.155

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

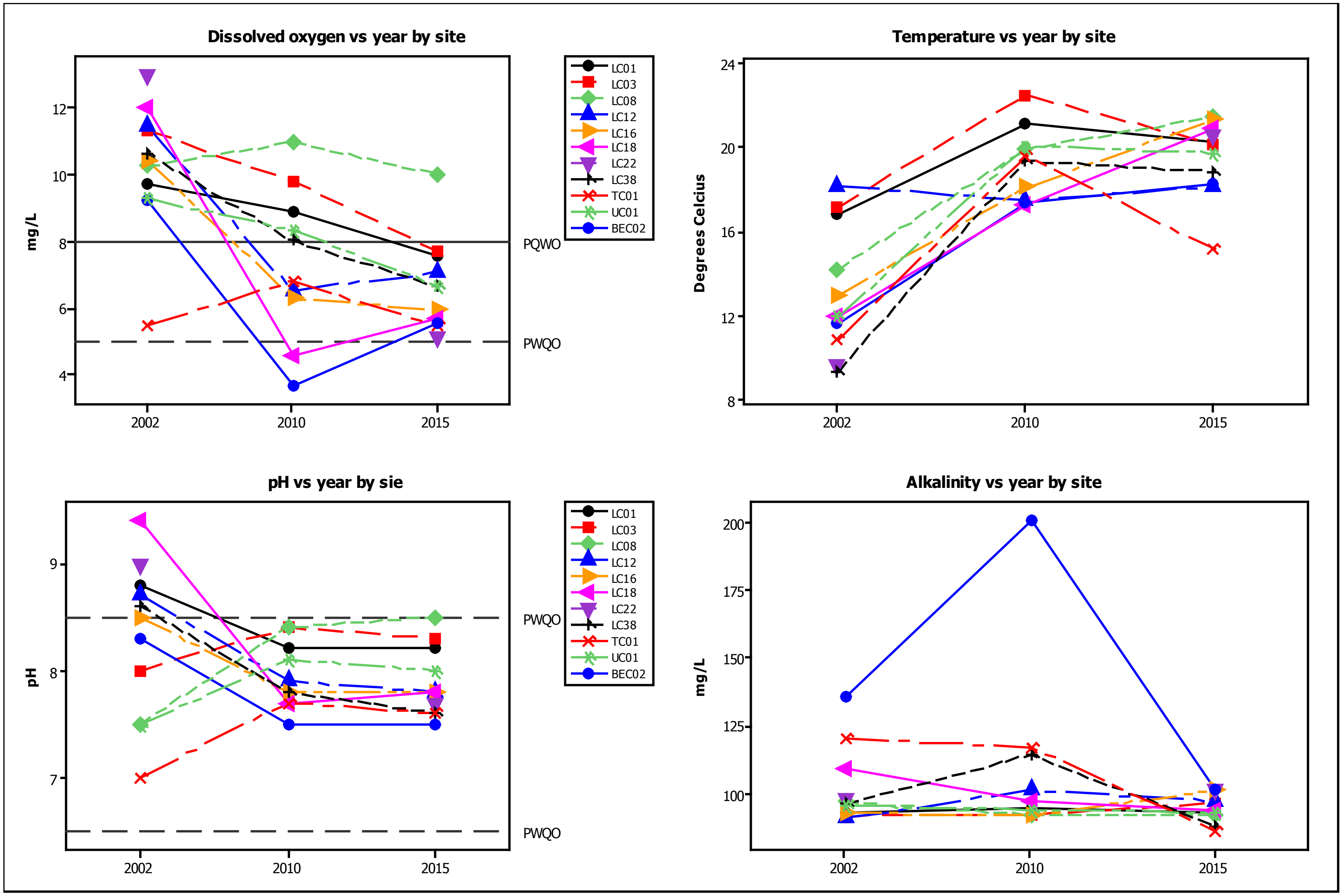


Figure B2. Trends in dissolved oxygen, temperature pH, and alkalinity of overlying water from co-located Lyons Creek East and reference creeks sampled 2002-2015. LC = Lyons Creek, TC = Tee Creek, UC = Usshers Creek, BEC = Beaver Creek.

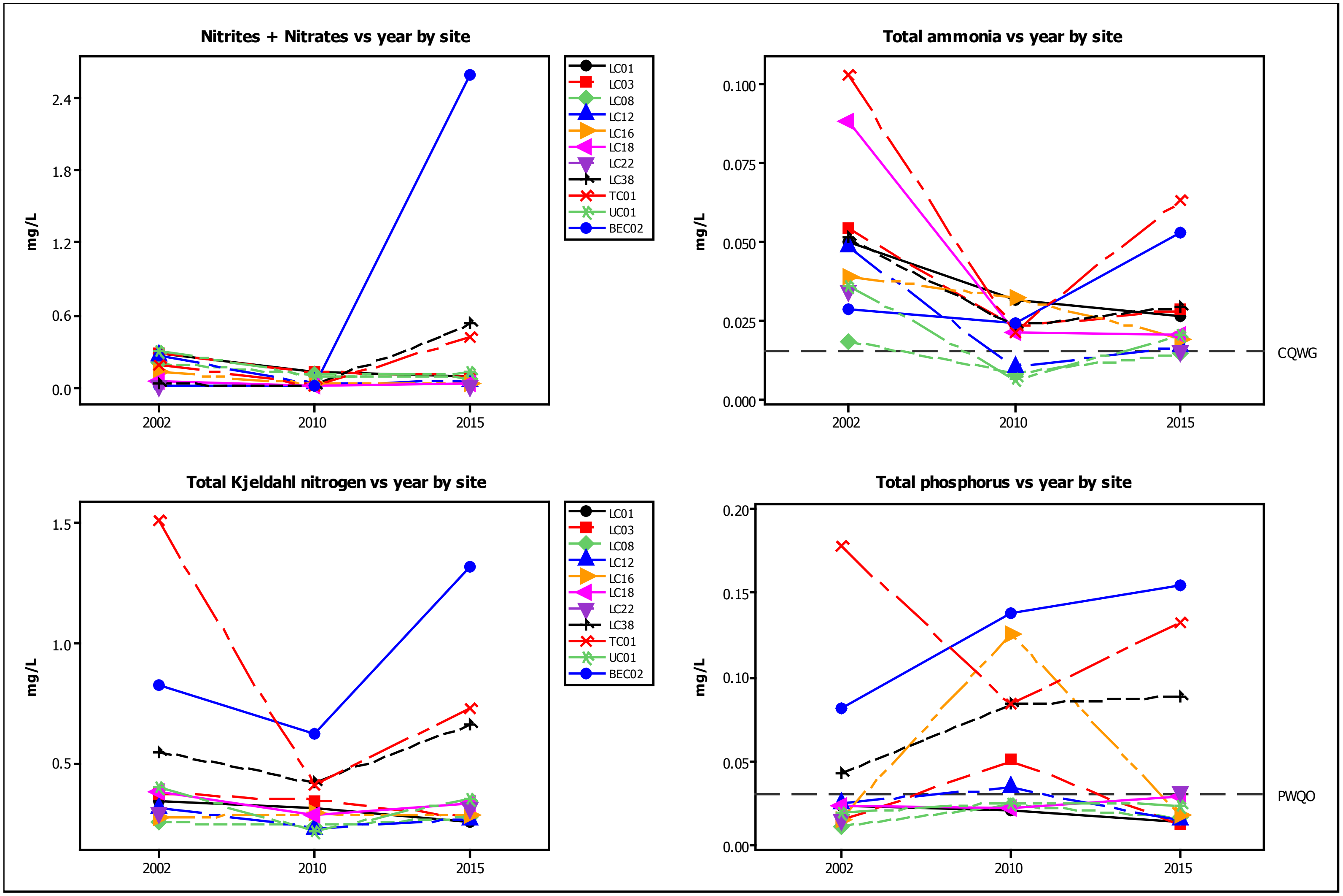


Figure B3. Trends in concentrations of nitrates+nitrites, ammonia, total Kjeldahl nitrogen and total phosphorus in the overlying water from co-located Lyons Creek East (LC) and reference sites sampled 2002-2015. LC = Lyons Creek, TC = Tee Creek, UC = Usshers Creek, BEC = Beaver Creek.

Table B3. Major oxides (%) and particle size distribution in 2015 Lyons Creek East and reference creek sediments. LC = Lyons Cree, TC = Tee Creek, Usshers Creek, BEC = Beaver Creek.

Parameter	Units	M.D.L.	**LC01**	**LC03**	**LC08**	**LC12[a]**	**LC16[b]**	**LC18**	**LC22**	**LC38**	**TC01**	**UC01**	**BEC02**
Aluminum (Al2O3)	%	0.04	9.48	9.81	13.3	12	13.3	14.4	14.2	10.1	13.2	8.98	11.8
Barium (BaO)	%	0.002	0.036	0.037	0.042	0.042	0.043	0.046	0.044	0.035	0.043	0.043	0.049
Calcium (CaO)	%	0.06	12.7	5.06	2.02	6.17	6.88	5.25	1.42	11.2	2.15	2.73	3.09
Chromium (Cr2O3)	%	0.006	0.008	0.021	0.014	0.015	0.014	0.012	0.013	0.011	0.011	0.006	0.008
Iron (Fe2O3)	%	0.01	4.27	10.7	6.22	5.8	6.43	6.67	6.44	5.96	5.86	3.37	4.28
Potasium (K20)	%	0.2	2.1	2	2.9	2.4	2.8	3.0	2.9	2.3	2.7	1.8	2.5
Magnesium (MgO)	%	0.03	3.25	2.15	2.61	2.14	2.6	2.59	2.28	2.63	2.23	1.65	2.35
Manganese (MnO)	%	0.003	0.104	0.086	0.065	0.063	0.085	0.08	0.076	0.228	0.109	0.073	0.072
Sodium (Na2O)	%	0.5	0.8	0.6	0.8	0.8	0.7	0.7	0.8	0.7	0.8	1.5	1.3
Phosphorus (P2O5)	%	0.5	< 0.5	0.9	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Silica (SiO2)	%	0.1	47	41.4	53.6	52.9	50.1	55.2	57	44.7	57.1	62.1	68.5
Titanium (TiO2)	%	0.02	0.55	0.52	0.78	0.71	0.74	0.81	0.83	0.57	0.77	0.67	0.7
Whole Rock Total	%		97.9	92.8	104	102	104	106	103	93.8	101	90.4	105
% Sand	> 62 um - 2 mm		10.9	12.7	7.7	6.0	2.4	2.2	5.6	18.2	7.9	46.2	32
% Silt	4 - 62 um		54.5	45.3	50	52	42	49.5	51.2	46.7	53.6	33.6	32.9
% Clay	< 4 um		33.2	40.1	42.3	42	56	48.3	43.2	35.1	38.4	13.6	35.1

Table B4. Biota-sediment accumulation factors for Lyons Creek East and reference creeks, based on paired sediment and amphipod observations. LC = Lyons Cree, TC = Tee Creek, Usshers Creek, BEC = Beaver Creek.

BSAF AMPHIPODS

Site	PCB 81	PCB 77	PCB 126	PCB 169	PCB 105	PCB 114	PCB 118	PCB 123	PCB 156/15	PCB 167	PCB 189
LC01		0.61			1.11		1.35		0.92	1.02	
LC08		1.66			1.54		1.70		1.70	1.42	
LC12		0.56	0.32		0.51	0.92	0.57	0.35	0.51	0.59	0.26
LC16	1.63	1.32	0.65		1.30	1.44	1.34	1.50	0.85	0.84	0.44
LC18		0.65	0.26		0.62	0.76	0.68	0.53	0.46	0.48	0.24
LC22		2.13	0.85		2.45	2.77	2.67	2.56	1.81	1.97	0.83
LC38		2.20			3.93		4.60		2.28	2.40	
TC01		3.74	0.63		6.49		8.06		2.93	2.84	1.81
UC01		13.47					19.59		3.51		
BEC02		2.76			3.33		4.61		1.30	1.44	

BSAF CHIRONOMIDS

Site	PCB 81	PCB 77	PCB 126	PCB 169	PCB 105	PCB 114	PCB 118	PCB 123	PCB 156/15	PCB 167	PCB 189
LC16	0.40	0.34	0.16		0.43	0.37	0.44	0.40	0.32	0.31	
LC18		0.14			0.09		0.14			0.34	
LC22		1.01			1.09	1.47	1.15	1.05	0.77	0.76	0.64
LC38		1.34			2.74		3.13		1.59	1.78	
TC01		1.06			2.37		2.64		1.57		1.41
UC01		6.19					8.46				
BEC02					1.73		2.23		1.21		

BSAF OLIGOCHAETES

Site	PCB 81	PCB 77	PCB 126	PCB 169	PCB 105	PCB 114	PCB 118	PCB 123	PCB 156/15	PCB 167	PCB 189
LC16	0.17	0.17			0.25	0.19	0.23		0.24	0.23	0.21
LC22		0.11					0.27			0.63	
UC01		2.50					5.85				
BEC02					0.75						

Lyons Creek East overall range: 0.24 – 4.60 (avg. 1.29); Reference Creek overall range: 0.63 – 19.59 (avg. 5.10)

APPENDIX C

Macroinvertebrate counts

Table C1. Lowest level invertebrate counts (per area of sampling device) for 2015 Lyons Creek East and reference creek samples. LC = Lyons Creek East, TC=Tee Creek, UC=Usshers Creek, BEC = Beaver Creek.

	LC01			LC03					LC08					LC1200					LC1201					LC1202				
TAXA	**P1**	**P2**	**P3**	**i**	**ii**	**iii**	**iv**	**v**	**i**	**ii**	**iii**	**iv**	**v**	**i**	**ii**	**iii**	**iv**	**v**	**i**	**ii**	**iii**	**iv**	**v**	**i**	**ii**	**iii**	**iv**	**v**
OLIGOCHAETA																												
Aulodrilus americanus																												
Aulodrilus limnobius			1																									
Aulodrilus pigueti			2							1				1			1	1		1		1	1			1		
Aulodrilus pluriseta	2	1	2	3	2			2																				
Branchiura sowerbyi	1																											
Dero digitata			2																									
Dero nivea																												
Eiseniella tetraedra													1															
Enchytraeus	1	1																										
Ilyodrilus templetoni	13	6																										
Limnodrilus cervix	3	2	4																									
Limnodrilus claparedeianus	1				1																							
Limnodrilus hoffmeisteri	35	15	4		14	33		8				1	1		1								1					
Limnodrilus udekemianus	33	43	11																	1								
Lumbricidae										1	1																	
Nais variabilis																												
Potamothrix moldaviensis	1	5	3																									
Potamothrix vejdovskyi		1																										
Specaria josinae																												
Stylaria lacustris [=fossularis]																												
Quistadrilus multisetosus	32	28	1	6	1		2	5																				
Uncinais uncinata																												
Tubificinae imm. + hairs	52	43	20	2		6		3								1		1		1			1					
Tubificinae imm. - hairs	352	177	29	115	56	129	43	59	3	3	1		2	3	5	6	8	3	2	3	1	8	6	2	4	4	5	4
NEMERTEA																												
Prostoma																												
TURBELLARIA																												
Dugesia tigrina																												
Hydrolimax grisea																												
HIRUNDINEA																												
Desserobdella phalera																												
Helobdella stagnalis										1																		
Helobdella triserialis			2																									
Gloiobdella elongata				1																								
Glossiphonia complanata																												
AMPHIPODA																												
Gammarus [tiny indiv.]										2							1				1			1			1	
Gammarus fasciatus																												
Gammarus pseudolimnaeus									1		17		4															
Hyalella azteca [cmplx]																	1											

Table C1. Continued.

	LC16			LC18			LC22					LC38			TC01			BEC02			UC01				
TAXA	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**i**	**ii**	**iii**	**iv**	**v**	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**i**	**ii**	**iii**	**iv**	**v**
OLIGOCHAETA																									
Aulodrilus americanus																								1	
Aulodrilus limnobius														2						1	3				2
Aulodrilus pigueti	1		1	2		2			1	2	1	16	25	28	3	3	4	42	35	5	1	1	1		3
Aulodrilus pluriseta																		1				1	2	4	3
Branchiura sowerbyi																					3		2		4
Dero digitata																			5						2
Dero nivea			2															5	2	2					
Eiseniella tetraedra																					1	1	1		
Enchytraeus						1																			
Ilyodrilus templetoni						1						5	6	7				1	5						
Limnodrilus cervix																		7							
Limnodrilus claparedeianus																									
Limnodrilus hoffmeisteri			2	1		2				1		3	9	2	2		1	8	14		2			3	
Limnodrilus udekemianus																							2		1
Lumbricidae																							1		
Nais variabilis			1																						
Potamothrix moldaviensis																									
Potamothrix vejdovskyi																									
Specaria josinae								1				2		2	1				1						
Stylaria lacustris [=fossularis]	1				1										4		1				1				
Quistadrilus multisetosus																									
Uncinais uncinata																					1				
Tubificinae imm. + hairs				4		2		1	1		1	22	31	45	4	6	2	48	47	6	9	20	6	16	27
Tubificinae imm. - hairs	8	2	1	4	7	1		4	1	1	3	48	39	65	10	26	3	177	177	17	32	49	22	56	67
NEMERTEA																									
Prostoma						1																			
TURBELLARIA																									
Dugesia tigrina	24	3	5	1	3	3									1	5	1								
Hydrolimax grisea	1													1		1			4						
HIRUNDINEA																									
Desserobdella phalera	1																								
Helobdella stagnalis																									
Helobdella triserialis					2																		1		
Gloiobdella elongata																								1	
Glossiphonia complanata																					1				
AMPHIPODA																									
Gammarus [tiny indiv.]																			2						
Gammarus fasciatus																				2					
Gammarus pseudolimnaeus	2	1	2													2									
Hyalella azteca [cmplx]	38	24	39	36	4	9									13	48	7	1		1					

Table C1. Continued.

	LC01			LC03					LC08					LC1200					LC1201					LC1202				
TAXA	P1	P2	P3	i	ii	iii	iv	v	i	ii	iii	iv	v	i	ii	iii	iv	v	i	ii	iii	iv	v	i	ii	iii	iv	v
ISOPODA																												
Caecidotea [tiny indiv.]									3			6																
Caecidotea racovitzai										8	6		7															
ACARI																												
Arrenurus																												
Hydrodroma despiciens																		1			1	1			1	1	1	
Laversia																												
Limnesia	1				1												1			1				1				1
Oxus																												
Piona																	1						1				1	
Unionicola [deutonynph]																												
ODONATA																												
Coenagrionidae							1																					
Enallagma cyathigerum																												
Enallagma signatum																												
Somatochlora [early instar]																											1	
EPHEMEROPTERA																												
Baetidae																												
Caenis						1		1						1		1	2					1	2				1	
Caenis latipennis																												
Caenis punctata	1																						1					
Callibaetis																												
Hexagenia limbata																												
Stenonema femoratum																												
HEMIPTERA																												
Corixidae [nymph]																1												
LEPIDOPTERA																												
Acentria nivea [monotypic]			3																									
Paraponyx																												
MEGALOPTERA																												
Sialis																												
TRICHOPTERA																												
Leptocerus americanus																			1									
Oecetis inconspicua [cmplx]										2					1			2	1				1					1
Oecetis osteni																												
Orthotrichia			1														1											
Oxyethira					1																							
Phryganea cinerea																												
Phylocentropus carolinus																												
Polycentropus			1																									
Triaenodes																												
Triaenodes melacus			1																									
COLEOPTERA																												
Donacia																												
Dubiraphia	6	3	3	1			1																					
HYMENOPTERA																												
Braconidae [semiaquatic, parasitic]																												
DIPTERA:Ceratopogonidae																												
Bezzia							1										1											
Culicoides														7	3	4	13	5	7	5	6	14	14	10	4	19	13	14
Mallochohelea																2	2	1									5	
Probezzia																							5	1	2	6		6
Sphaeromais														1	3	1		2		3		2	2		2	1	1	1

Table C1. Continued.

	LC16			LC18			LC22					LC38			TC01			BEC02			UC01				
TAXA	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**i**	**ii**	**iii**	**iv**	**v**	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**i**	**ii**	**iii**	**iv**	**v**
ISOPODA																									
Caecidotea [tiny indiv.]												2		2											
Caecidotea racovitzai																					10	1	12	2	4
ACARI																									
Arrenurus			1											4	1										
Hydrodroma despiciens	2		2		1	1																			
Laversia																		1							
Limnesia	2	1	1	1					1																
Oxus																1									
Piona																									
Unionicola [deutonynph]																1									
ODONATA																									
Coenagrionidae	2	1	1		1										1	1		1	1	1			1		
Enallagma cyathigerum	2			13	3	1									1	3									
Enallagma signatum	5	1	3	10	3	2										1		1		2					
Somatochlora [early instar]	1		1																						
EPHEMEROPTERA																									
Baetidae																					1				
Caenis	4		5	1				1					1		1	1		3		3	1	1			
Caenis latipennis	5																	1			1		1	1	
Caenis punctata	4	5	5		3	2									1	5		10	1	4					
Callibaetis	4		4													1									
Hexagenia limbata												1						1							
Stenonema femoratum																					1				
HEMIPTERA																									
Corixidae [nymph]		1										3	5	2	5			1		1					
LEPIDOPTERA																									
Acentria nivea [monotypic]																									
Paraponyx				1																					
MEGALOPTERA																									
Sialis												1		2			1								
TRICHOPTERA																									
Leptocerus americanus	4				2										2										
Oecetis inconspicua [cmplx]	1	1														1									
Oecetis osteni	4	1	3		1																				
Orthotrichia	6	1	3			2								1	1	4		1		1					
Oxyethira															3	5		4							
Phryganea cinerea		1																							
Phylocentropus carolinus													1		2	4									
Polycentropus			2																						
Triaenodes																					1				
Triaenodes melacus																									
COLEOPTERA																									
Donacia											1														
Dubiraphia												2	2		3	7	3	3	7	3	2	6	4		5
HYMENOPTERA																									
Braconidae [semiaquatic, parasitic]				1																					
DIPTERA:Ceratopogonidae																									
Bezzia	1																								
Culicoides	3	3	2								1							1							
Mallochohelea	4		3													2			1						
Probezzia								6	1	5	1							1						1	1
Sphaeromais					1								2		1	1									

Table C1. Continued.

	LC01			LC03					LC08					LC1200					LC1201					LC1202				
TAXA	**P1**	**P2**	**P3**	**i**	**ii**	**iii**	**iv**	**v**	**i**	**ii**	**iii**	**iv**	**v**	**i**	**ii**	**iii**	**iv**	**v**	**i**	**ii**	**iii**	**iv**	**v**	**i**	**ii**	**iii**	**iv**	**v**
DIPTERA:Chironomidae																												
Tanypodinae																												
Ablabesmyia [early instar]																												
Ablabesmyia peleensis																												
Ablabesmyia annulata																												
Clinotanypus pinguis	1														1	2	1	1					1			1		
Coelotanypus scapularis																												
Labrundinia [sp. C Epler]																												
Labrundinia neopilosella																												
Procladius										1			1	9	6	4	12	6	2	8	12	11	6	2	3	7	3	7
Tanypus punctipennis																			1	4	1			1	1			
Orthocladiinae																												
Corynoneura																												
Cricotopus		1			1		1																					
Cricotopus bicinctus																												
Cricotopus flavocinctus								1																				
Cricotopus lebetis																												
Cricotopus myriophylli																												
Epoicocladius flavens																												
Nanocladius alternantherea						1																						
Psectrocladius simulans						2																						
Thienemaniella lobapodema																												
Chironominae:Chironomini																												
Chironomus [early instar]															1													
Chironomus decorus [grp]	1	2																										
Cladoopelma						1											1	1	1	1			1			1		3
Cryptochironomus	2	2	1									1		1		2	3			1	2	7	1	1	4	9	6	7
Cryptotendipes																	1		1	1			1	1	1		1	2
Cryptotendipes emorsus			1																									
Dicrotendipes [early instars]				1	1	1								4				3		1		2	5	4	3	2	7	7
Dicrotendipes modestus																			1		2			1	1		1	
Dicrotendipes neomodestus																												
Einfeldia natchitocheae																												
Glyptotendipes dreisbachi																												
Endochironomus nigricans																												
Microtendipes pedellus [grp]																												
Parachironomus potamogeti																												
Paralauterborniella nigrohalteralis												1				1	1	1	1	1				1	1	2		
Phaenopsetra [early instar]																												
Polypedilum fallax [grp]																				1								1
Polypedilum illinoense																												
Polypedilum halterale [grp]		1								1		4	1	1	2	7	10	2	5	4	1	4	4	6	6	4	11	11
Tribelos jucundum	3	1	2																1			1			1		1	
Chironominae:Pseudochironomini																												
Pseudochironomus			2																									
Chironominae:Tanytarsini																												
Cladotanytarsus																												
Paratanytarsus							1																					
Tanytarsus	1																2		1	3			2	2	1	1	6	1
Zavreliella marmorata																												

Table C1. Continued.

	LC16			LC18			LC22					LC38			TC01			BEC02			UC01				
TAXA	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**i**	**ii**	**iii**	**iv**	**v**	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**i**	**ii**	**iii**	**iv**	**v**
DIPTERA:Chironomidae																									
Tanypodinae																									
Ablabesmyia [early instar]	3																								
Ablabesmyia peleensis																		1							
Ablabesmyia annulata													1	1				2		1					
Clinotanypus pinguis						2							5	1	1	5	1	3	3	4					1
Coelotanypus scapularis												1													
Labrundinia [sp. C Epler]														1	2	1									
Labrundinia neopilosella			1	1												4									
Procladius	41	6	17	9	5	6			1	1		15	14	27	11	17	1	13	13	1	1	3	4	5	1
Tanypus punctipennis	1		1												2	2									
Orthocladiinae																									
Corynoneura						2					1				7	6									
Cricotopus	1	2															1								
Cricotopus bicinctus															15	5						1			
Cricotopus flavocinctus	18	5	9	2	6											2									
Cricotopus lebetis	1														2			1							
Cricotopus myriophylli	1		2													1	1								
Epoicocladius flavens												2	1												
Nanocladius alternantherea	9		3			1									3	1									
Psectrocladius simulans			1												4	4		2		1					
Thienemaniella lobapodema															1										1
Chironominae:Chironomini																									
Chironomus [early instar]								1				2	2	1	1			8	5						
Chironomus decorus [grp]												2						7	1						
Cladoopelma	1	1										1	1					4	2						
Cryptochironomus	1	2	1						3	1															
Cryptotendipes										1													1	1	
Cryptotendipes emorsus												6	4	1											1
Dicrotendipes [early instars]	19	1	8		3	1				1			1		9		1	33	1	4					1
Dicrotendipes modestus	17	2	3		1	1						2		1	4	5	1	19	5	1					1
Dicrotendipes neomodestus	3	3	3	1	2	2					1		1		5	11									
Einfeldia natchitocheae				2																					
Glyptotendipes dreisbachi																	1			3					
Endochironomus nigricans																		1			1				
Microtendipes pedellus [grp]	1		1													1									
Parachironomus potamogeti	6	1	1																						
Paralauterborniella nigrohalteralis				2	2				1	5		2	1	2		1	1						1		
Phaenopsetra [early instar]															1										
Polypedilum fallax [grp]																									
Polypedilum illinoense				3	1										6	3	1								
Polypedilum halterale [grp]	5		2		1	5		2			1	3	5			1		2	3						
Tribelos jucundum				3		1					2	55	34	48	23	48	12	93	140	15		1	1		
Chironominae:Pseudochironomini																									
Pseudochironomus		1		4	3	8									3	1									
Chironominae:Tanytarsini																									
Cladotanytarsus									1	2				1		1	1							1	
Paratanytarsus	11	3	13	6	6	5					4	1	1		14	21		2		1					
Tanytarsus	16	1	6		3	3		1	2	2	2	1	2	2	3	2		4	2		3		1		2
Zavreliella marmorata									1	1			1	3		1	1		1						

Table C1. Continued.

	LC01			LC03					LC08					LC1200					LC1201					LC1202				
TAXA	**P1**	**P2**	**P3**	**i**	**ii**	**iii**	**iv**	**v**	**i**	**ii**	**iii**	**iv**	**v**	**i**	**ii**	**iii**	**iv**	**v**	**i**	**ii**	**iii**	**iv**	**v**	**i**	**ii**	**iii**	**iv**	**v**
DIPTERA:Empididae																												
Hemerodromia					1																							
DIPTERA:Ephydridae																												
Ephydra																												
Hydrellia				1		1																						
DIPTERA:Tabanidae																												
Chrysops mitis																												
Chrysops niger																1												
GASTROPODA																												
Amnicola limosa			1																									
Ferrissia rivularis				1	1																							
Gyraulus							3																					
Gyraulus deflectus																												
Helisoma anceps																												
Physa																												
Physa gyrina																												
Planorbidae [decalcified]																												
Pyrgulopsis lustrica				1																								
Valvata piscinalis				1									1	1										1			1	
Valvata sincera									2	2	1	1																
Valvata tricarinata																												
BIVALVIA																												
Dreissena bugensis	1		1																									
Musculium [new borns]																												
Musculium partumeium																												
Pisidium [young/damaged/decalcified]				1	1		1											1								1		
Pisidium casertanum																												
Pisidium compressum	1																											
Pisidium fallax									1		1		2												1			
Pisidium ferrugineum								1																				
Pisidium lilljeborgi								1		4																		
Pisidium nitidum				2			1	3		3	2	1					1						1		1			1
Pisidium variabile								3																				

Table C1. Continued.

	LC16			LC18			LC22					LC38			TC01			BEC02			UC01				
TAXA	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**i**	**ii**	**iii**	**iv**	**v**	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**i**	**ii**	**iii**	**iv**	**v**
DIPTERA:Empididae																									
Hemerodromia																									
DIPTERA:Ephydridae																									
Ephydra															1										
Hydrellia				1		1																	1		
DIPTERA:Tabanidae																									
Chrysops mitis																			1						
Chrysops niger																									
GASTROPODA																									
Amnicola limosa	2	1	2												2	1		1		1					
Ferrissia rivularis				4		8																1	1		
Gyraulus					2																				
Gyraulus deflectus				1																					
Helisoma anceps						2																			
Physa																							2		
Physa gyrina						1												3							
Planorbidae [decalcified]																1		1	1	3					
Pyrgulopsis lustrica	1																								
Valvata piscinalis																									
Valvata sincera																									
Valvata tricarinata																1		1							
BIVALVIA																									
Dreissena bugensis																									
Musculium [new borns]												20	14	17				2	9			4			
Musculium partumeium												2													
Pisidium [young/damaged/decalcified]												3	8	15		1		15	17	1			1		
Pisidium casertanum													1												
Pisidium compressum						1						5	3	3		1		1							
Pisidium fallax																								1	
Pisidium ferrugineum																									
Pisidium lilljeborgi						1						2	3	4								1			
Pisidium nitidum												1				1			3	1					
Pisidium variabile																									

Table C2. Family counts (per m^{-2}), taxon richness, and total abundance for 2015 Lyons Creek East and reference creek sites. LC = Lyons Creek East, TC=Tee Creek, UC=Usshers Creek, BEC = Beaver Creek.

Site	Ref creek avg (SD)	TC01	UC01	BEC02	LC01	LC03	LC08	LC12[a]	LC16	LC18	LC22	LC38
Zone	Reference	REF	REF	REF	1 - u/s	1	2	2	3	4	5	d/s Ref
No. Taxa	20 (4)	24	16	18	14	16	9	16	21	20	6	14
Total Abundance	16304 (10532)	6600	27503	14809	12731	32207	6212	12988	6876	3424	4403	9752
Naididae[c]	9922 (10156)	915	20929	7921	12091	29554	724	1568	249	353	1086	4667
Chironomidae	3652 (1633)	3712	1990	5255	274	663	603	6675	3333	1347	2292	3347
Hyalellidae	305 (506)	889	0	26.3	0	0	0	20.1	1320	640	0	0
Gammaridae	26 (26)	26.3	0	52.5	0	0	1448	80.4	65.5	0	0	0
Caenidae	231 (110)	105	302	287	12.9	121	0	181	366	78.4	60.3	12.9
Pisidiidae	367 (305)	38.8	422	640	12.9	844	844	141	0	25.9	0	1320
Limnesiidae	0 (0)	0	0	0	12.9	60.3	0	80.4	52.2	12.9	60.3	0
Hydroptilidae	83 (85)	170	0	78.4	12.9	60.3	0	20.1	131	26.3	0	12.9
Ceratopogonidae	71 (44)	52.5	120.6	38.8	0	60.3	0	3780	209	12.9	844	26.3
Leptoceridae	33 (31)	39.2	60.3	0	12.9	0	121	141	183	39.2	0	0
Glossiphoniidae	60 (104)	0	181	0	26.3	60.3	60.3	0	12.9	26.3	0	0
Coenagrionidae	77 (16)	91.4	60.3	78.4	0	60.3	0	0	196	431	0	0
Valvatidae	8.6 (7)	12.9	0	12.9	0	60.3	422	60.3	0	0	0	0
Elmidae	455 (494)	170	1025	170	157	121	0	0	0	0	0	52.2
Asellidae	583 (1010)	0	1749	0	0	0	1809	0	0	0	0	52.2
Planariidae	30 (53)	91.4	0	0	0	0	0	0	418	91.4	0	0
Ancylidae	40 (70)	0	121	0	0	121	0	0	0	157	0	0
Planorbidae	26 (35)	12.9	0	65.5	0	181	0	0	0	65.5	0	0
Lumbricidae	80 (139)	0	241	0	0	0	181	0	0	0	0	0
Corixidae	31 (33)	65.5	0	26.3	0	0	0	20.1	12.9	0	0	131
Ephydridae	24 (32)	12.9	60.3	0	0	121	0	0	0	26.3	0	0
Hydrobiidae	22 (20)	39.2	0	26.3	12.9	60.3	0	0	78.4	0	0	0
Hydrodromidae	0 (0)	0	0	0	0	0	0	121	52.2	26.3	0	0
Baetidae	24 (32)	12.9	60.3	0	0	0	0	0	105	0.0	0	0
Physidae	53 (62)	0	121	39.2	0	0	0	0	0	12.9	0	0
Dipseudopsidae	26 (45)	78.4	0	0	0	0	0	0	0	0	0	12.9
Plagiostomidae	22 (27)	12.9	0	52.2	0	0	0	0	12.9	0	0	12.9
Arrenuridae	4 (7)	12.9	0	0	0	0	0	0	12.9	0	0	52.2
Pionidae	0 (0)	0	0	0	0	0	0	60.3	0	0	0	0
Chrysomelidae	0 (0)	0	0	0	0	0	0	0	0	0	60.3	0
Empididae	0 (0)	0	0	0	0	60.3	0	0	0	0	0	0
Heptageniidae	20 (35)	0	60.3	0	0	0	0	0	0	0	0	0
Sialidae	4 (7)	12.9	0	0	0	0	0	0	0	0	0	39.2
Corduliidae	0 (0)	0	0	0	0	0	0	20.1	26.3	0	0	0
Enchytraeidae	0 (0)	0	0	0	26.3	0	0	0	0	12.9	0	0
Polycentropodidae	0 (0)	0	0	0	12.9	0	0	0	26.3	0	0	0
Pyralidae	0 (0)	0	0	0	39.2	0	0	0	0	0	0	0
Tabanidae	4 (7)	0	0	12.9	0	0	0	20.1	0	0	0	0
Dreissenidae	0 (0)	0	0	0	26.3	0	0	0	0	0	0	0
Ephemeridae	4 (7)	0	0	12.9	0	0	0	0	0	0	0	12.9
Crambidae	0 (0)	0	0	0	0	0	0	0	0	12.9	0	0
Phryganeidae	0 (0)	0	0	0	0	0	0	0	12.9	0	0	0
Tetrastemmatidae	0 (0)	0	0	0	0	0	0	0	0	12.9	0	0
Oxidae	4 (7)	12.9	0	0	0	0	0	0	0	0	0	0
Unionicolidae	4 (7)	12.9	0	0	0	0	0	0	0	0	0	0

APPENDIX D

Results of correlation with nonmetric multidimensional scaling axes - benthic community composition data

Table D1. Correlation of invertebrate families with individual NMS axes 1 and 2 for 2015 Lyons Creek East and neighbouring reference creek data.

Pearson and Kendall Correlations with Ordination Axes N= 11

Axis:	1			2		
	r	r-sq	tau	r	r-sq	tau
Naididae	.935	.874	.891	.304	.092	.236
Chironom	-.889	.791	-.564	.319	.102	.164
Ceratopo	-.398	.159	-.514	.436	.190	.220
Pisidiid	.215	.046	.183	-.675	.456	-.330
Asellida	.154	.024	.182	-.914	.835	-.597
Hyalelli	-.717	.514	-.640	-.079	.006	-.128
Elmidae	.385	.148	.503	.121	.015	-.060
Gammarid	.042	.002	-.426	-.903	.816	-.128
Caenidae	-.696	.485	-.564	.159	.025	.018
Coenagri	-.485	.235	-.342	-.151	.023	-.382
Planarii	-.649	.421	-.649	-.058	.003	-.285
Leptocer	-.604	.365	-.520	-.528	.278	-.327
Valvatid	.057	.003	-.043	-.888	.788	.085
Hydropti	-.593	.352	-.337	.073	.005	-.037
Ancylida	-.295	.087	.078	-.155	.024	-.337
Glossiph	.109	.012	.060	-.815	.665	-.543
Planorbi	-.243	.059	.000	-.082	.007	-.046
Limnesii	-.513	.263	-.302	.368	.135	.382
Corixida	-.171	.029	-.256	.076	.006	-.043
Ephydrid	-.112	.013	.046	-.077	.006	-.277
Hydrobii	-.452	.204	.000	.090	.008	.043
Hydrodro	-.699	.488	-.545	.124	.015	.026
Baetidae	-.441	.194	-.234	.000	.000	-.234
Physidae	.095	.009	.078	-.072	.005	-.337
Plagiost	-.231	.054	-.139	.140	.020	.046
Arrenuri	-.159	.025	-.234	.005	.000	-.182

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Table D2. Correlation of environmental variables with individual NMS axes 1 and 2 for 2015 Lyons Creek East and neighbouring reference creek data.

Pearson and Kendall Correlations with Ordination Axes N= 11

Axis:		1			2	
	r	r-sq	tau	r	r-sq	tau
Al2O3	-.842	.708	-.587	-.253	.064	-.183
BaO	-.518	.268	-.321	-.079	.006	-.057
CaO	.168	.028	.055	.255	.065	.127
Cr2O3	-.313	.098	-.315	-.062	.004	.093
Fe2O3	-.226	.051	-.309	-.047	.002	-.091
K20	-.791	.625	-.514	-.336	.113	-.183
MgO	-.075	.006	-.018	-.166	.027	-.164
MnO	.133	.018	.127	.130	.017	-.018
Na2O	.301	.091	.195	.041	.002	.078
SiO2	-.238	.056	-.055	-.045	.002	-.055
TiO2	-.755	.569	-.527	-.284	.081	-.164
Al	-.716	.513	-.636	.023	.001	.091
As	.024	.001	-.273	.055	.003	.164
Cr	-.223	.050	-.367	.005	.000	.183
Cu	-.130	.017	-.257	.021	.000	.183
Fe	-.171	.029	-.491	.092	.008	.164
Pb	-.086	.007	-.389	-.004	.000	.093
Mg	.158	.025	-.055	.074	.006	.018
Mn	-.047	.002	-.091	.332	.110	.200
Hg	-.299	.089	-.294	.133	.018	.257
Ni	-.096	.009	-.330	.102	.010	.257
Zn	-.192	.037	-.345	.021	.000	.164
TKN	-.721	.520	-.491	-.419	.176	-.127
TP	.066	.004	-.273	.088	.008	.164
TOC	.065	.004	-.127	-.468	.219	.164
sumPAHs	.500	.250	.236	.074	.006	.018
TPHCs	.061	.004	-.236	-.131	.017	-.018
sand	.664	.440	.600	.078	.006	-.055
silt	-.244	.059	-.091	-.003	.000	.200
clay	-.686	.470	-.661	-.084	.007	.000
PCB-077	-.247	.061	-.273	-.088	.008	.164
PCB-081	-.134	.018	-.200	-.082	.007	.091
PCB-126	-.276	.076	-.273	-.045	.002	.236
PCB-169	-.071	.005	-.091	-.181	.033	-.018
PCB-105	-.232	.054	-.236	-.101	.010	.127
PCB-114	-.206	.042	-.200	-.047	.002	.236
PCB-118	-.228	.052	-.236	-.096	.009	.127
PCB-123	-.168	.028	-.200	-.049	.002	.091
PCB-156/	-.207	.043	-.236	-.076	.006	.127
PCB-167	-.230	.053	-.236	-.077	.006	.127
PCB-189	-.238	.057	-.273	-.001	.000	.309
TEQ	-.223	.050	-.309	-.068	.005	.200
TPCBs	-.232	.054	-.273	-.071	.005	.164

Table D3. Correlation of invertebrate families with individual NMS axes 1, 2 and 3 for 2002-2015 time series Lyons Creek East and neighbouring reference creek data.

Pearson and Kendall Correlations with Ordination Axes N= 23

Axis:	1			2			3		
	r	r-sq	tau	r	r-sq	tau	r	r-sq	tau
Ancylida	.379	.144	.296	-.093	.009	.006	-.230	.053	-.238
Arrenuri	.263	.069	.198	.163	.027	.187	.117	.014	-.105
Asellida	.355	.126	.248	-.410	.168	-.200	.413	.170	.162
Baetidae	.284	.081	.230	-.330	.109	-.135	-.086	.007	-.230
Caenidae	.744	.553	.625	-.318	.101	-.206	.045	.002	.004
Ceratopo	.410	.168	.331	-.010	.000	.000	-.236	.056	-.234
Chironom	.875	.766	.644	-.049	.002	.036	-.098	.010	-.059
Coenagri	.739	.547	.580	-.123	.015	-.154	-.177	.031	-.138
Corixida	-.116	.014	-.024	.041	.002	-.071	.160	.026	-.008
Crangony	.520	.270	.426	.111	.012	.147	.066	.004	.035
Dreissen	.087	.008	-.056	.421	.177	.486	-.456	.208	-.153
Elmidae	.309	.095	.124	.502	.252	.477	-.242	.059	-.010
Enchytra	.240	.058	.077	-.014	.000	.021	.026	.001	-.049
Ephydrid	-.033	.001	-.035	.169	.028	.078	.261	.068	.134
Gammarid	.374	.140	.404	-.441	.194	-.332	.371	.138	.081
Glossiph	.133	.018	.109	.203	.041	.119	.081	.007	.043
Hyalelli	.797	.635	.600	-.303	.092	-.261	-.325	.106	-.294
Hydridae	.364	.133	.305	-.095	.009	.194	-.125	.016	-.264
Hydrobii	.366	.134	.203	.162	.026	.149	.174	.030	.149
Hydrodro	.060	.004	.110	-.205	.042	-.176	-.156	.024	-.132
Hydrophi	.312	.097	.166	.196	.038	.166	-.052	.003	-.182
Hydropti	.492	.242	.366	-.235	.055	-.157	-.025	.001	-.061
Leptocer	.607	.368	.385	-.251	.063	-.265	.019	.000	-.086
Limnesii	.143	.021	.095	.307	.094	.275	-.177	.031	-.221
Naididae	.386	.149	.281	.727	.529	.542	.401	.161	.320
Physidae	.417	.174	.285	-.058	.003	-.222	.144	.021	.021
Pionidae	.277	.077	.371	.125	.016	.050	.053	.003	-.006
Pisidiid	.105	.011	-.012	-.275	.076	-.211	.703	.494	.600
Plagiost	.693	.480	.555	-.126	.016	-.088	.114	.013	.067
Planarii	.546	.298	.409	.100	.010	.060	-.251	.063	-.256
Planorbi	.597	.357	.413	-.036	.001	.005	-.034	.001	-.166
Polycent	.550	.303	.397	-.102	.011	-.047	-.220	.048	-.163
Pyralida	.131	.017	.119	.214	.046	.244	.172	.030	.091
Tabanida	.514	.265	.453	-.265	.070	-.075	-.002	.000	-.088
Tetraste	.225	.051	.058	.373	.139	.198	-.406	.165	-.362
Trochoch	.341	.117	.246	.332	.110	.325	-.211	.045	-.135
Valvatid	-.119	.014	-.030	-.336	.113	-.152	.609	.371	.468

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Table D4. Correlation of environmental variables with individual NMS axes 1, 2 and 3 for 2002-2015 time series Lyons Creek East and neighbouring reference creek data.

Pearson and Kendall Correlations with Ordination Axes   N= 23

Axis:	1			2			3		
	r	r-sq	tau	r	r-sq	tau	r	r-sq	tau
Sand%	-.248	.061	-.225	.346	.120	.099	.178	.032	.320
Depth(m)	.096	.009	-.004	.502	.252	.378	-.280	.078	-.171
Ag (ppm)	.266	.071	.119	-.070	.005	.032	-.016	.000	.079
Al2O3 (p	.111	.012	.135	-.560	.314	-.414	-.211	.045	-.223
As (ppm)	.142	.020	.067	-.101	.010	-.123	.220	.049	.171
BaO (ppm	-.108	.012	.032	-.279	.078	-.314	.060	.004	-.209
CaO (ppm	-.187	.035	-.107	.521	.271	.375	-.184	.034	-.004
Co (ppm)	.110	.012	.080	-.176	.031	-.089	.135	.018	.105
Cr (ppm)	.172	.030	.111	-.125	.016	-.008	.265	.070	.199
Cu (ppm)	.166	.028	.107	.132	.017	.067	.113	.013	.107
Fe2O3 (p	-.111	.012	-.028	-.372	.139	-.257	.095	.009	-.004
Hg (ppm)	-.082	.007	-.087	-.147	.022	-.032	.198	.039	.166
K2O (ppm	.036	.001	.097	-.503	.253	-.357	-.081	.007	-.130
LOI (%)	.399	.159	.209	-.281	.079	-.194	.293	.086	.233
MgO (ppm	-.039	.002	-.016	.299	.089	.135	-.148	.022	-.087
Mn (ppm)	.105	.011	.091	.341	.116	.241	-.303	.092	-.170
Na2O (pp	-.462	.213	-.284	-.112	.013	-.067	-.140	.020	-.117
Ni (ppm)	.190	.036	.182	-.052	.003	-.040	.199	.040	.095
TKNs (pp	.266	.071	.138	-.682	.466	-.391	.194	.038	.115
Pb (ppm)	.281	.079	.150	-.096	.009	-.063	.259	.067	.214
SiO2 (pp	.169	.029	.138	-.024	.001	-.075	-.158	.025	-.186
Sr (ppm)	-.087	.008	-.048	.365	.133	.309	-.289	.084	-.111
TiO2 (pp	.071	.005	.052	-.475	.226	-.353	-.136	.019	-.194
TOC (%)	.020	.000	-.016	-.484	.234	-.342	.610	.372	.390
TPs (ppm	-.263	.069	-.225	-.385	.148	-.265	-.046	.002	.036
V (ppm)	-.311	.097	-.140	-.525	.276	-.324	.066	.004	-.020
Y (ppm)	-.144	.021	-.067	.522	.272	.345	.273	.074	.266
Zn (ppm)	.122	.015	.071	-.155	.024	-.079	.136	.018	.174
Alkalini	-.229	.052	-.032	-.413	.171	-.318	-.278	.077	-.334
DO (mg/L	.507	.257	.423	.167	.028	.083	.272	.074	.178
pH (pH)	.514	.265	.346	.014	.000	-.004	.182	.033	.085
TempBot	-.713	.508	-.486	.158	.025	.028	-.042	.002	.012
NH3 (mg/	.649	.421	.499	.331	.110	.253	-.049	.002	-.016
NO2+NO3	.155	.024	.138	.588	.346	.368	.295	.087	.194
TKNw (mg	.130	.017	.171	.112	.013	.083	.025	.001	-.107
TPw (mg/	-.226	.051	-.202	-.166	.028	-.146	.006	.000	-.051
TPAHs(ug	-.404	.163	-.202	-.061	.004	-.036	.219	.048	.123
TPCB(ug/	-.062	.004	-.083	-.145	.021	-.043	.183	.034	.130
TEQ1/2PC	.015	.000	-.115	-.255	.065	-.154	.200	.040	.099

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APPENDIX E

MRPP and ISA Results

Table E1. Multi-Response Permutation Procedures (MRPP) results for benthic community data, 2002-2015.

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MRPP LCE Time series 2002 to 2010

        Groups were defined by values of: Year
        Input data has:      23 sites    by     37 Families
        Weighting option: C(I) = n(I)/sum(n(I))
        Distance measure: Sorensen (Bray-Curtis)

     GROUP:     1
Identifier:  2002
      Size:     8      0.47516284    = Average distance
Members:
 LC01     LC03     LC08     LC12     LC16     LC18     LC38     LC22

     GROUP:     2
Identifier:  2010
      Size:     7      0.57218766    = Average distance
Members:
 LC01     LC03     LC08     LC12     LC16     LC18     LC38

     GROUP:     3
Identifier:  2015
      Size:     8      0.57043504    = Average distance
Members:
 LC01     LC03     LC08     LC12     LC16     LC18     LC38     LC22

        Test statistic: T =      -3.5414124
           Observed delta =      0.53783029
           Expected delta =      0.57280939
        Variance of delta =      0.97558330E-04
        Skewness of delta =     -0.80863554

        Chance-corrected within-group agreement, A =    0.06106587
          A = 1 - (observed delta/expected delta)
          Amax = 1 when all items are identical within groups (delta=0)
          A = 0 when heterogeneity within groups equals expectation by chance
          A < 0 with more heterogeneity within groups than expected by chance

        Probability of a smaller or equal delta, p =    0.00344889


-------------------------------------------------------------------
PAIRWISE COMPARISONS
Note: p values not corrected for multiple comparisons.

      Groups (identifiers)
       Compared             T             A             p
    2002  vs.   2010     -4.01420411    0.08251105    0.00430412
    2002  vs.   2015     -4.27366529    0.07802653    0.00213134
    2010  vs.   2015      1.43709757   -0.02344472    0.96260492
-------------------------------------------------------------------
```

Table E2. Indicator Species Analysis (ISA) results for benthic community data, 2002-2015.

INDICATOR VALUES (% of perfect indication, based on combining the values for relative abundance and relative frequency).

					Group		
				Sequence:	1	2	3
				Identifier:	2002	2010	2015
				Number of items:	8	7	8
Column		Avg	Max	MaxGrp			
1	Ancylida	10	24	2002	24	3	3
2	Arrenuri	11	25	2002	25	2	6
3	Asellida	16	27	2002	27	16	5
4	Baetidae	4	7	2002	7	1	5
5	Caenidae	29	47	2002	47	26	13
6	Ceratopo	27	43	2002	43	13	25
7	Chironom	33	50	2002	50	26	24
8	Coenagri	27	52	2002	52	23	5
9	Corixida	13	38	2015	0	0	38
10	Crangony	11	31	2002	31	2	0
11	Dreissen	7	16	2010	5	16	0
12	Elmidae	15	29	2002	29	12	5
13	Enchytra	8	17	2002	17	0	8
14	Ephydrid	9	18	2010	0	18	9
15	Gammarid	20	43	2002	43	7	10
16	Glossiph	16	21	2015	9	18	21
17	Hyalelli	26	58	2002	58	12	7
18	Hydridae	12	37	2002	37	0	0
19	Hydrobii	19	29	2010	26	29	3
20	Hydrodro	11	17	2015	7	7	17
21	Hydrophi	8	24	2002	24	1	0
22	Hydropti	20	24	2015	18	18	24
23	Leptocer	21	46	2002	46	9	6
24	Limnesii	16	21	2015	17	11	21
25	Naididae	33	45	2002	45	25	30
26	Physidae	16	42	2002	42	6	0
27	Pionidae	15	41	2002	41	3	1
28	Pisidiid	25	31	2010	15	31	30
29	Plagiost	25	74	2002	74	0	0
30	Planarii	18	50	2002	50	0	5
31	Planorbi	19	51	2002	51	5	2
32	Polycent	16	45	2002	45	0	2
33	Pyralida	11	29	2002	29	0	3
34	Tabanida	12	35	2002	35	0	0
35	Tetraste	11	25	2002	25	9	0
36	Trochoch	13	38	2002	38	0	0
37	Valvatid	11	25	2015	1	6	25
	Averages	17	35		31	10	10

MONTE CARLO test of significance of observed maximum
indicator value for Families. Significant families are highlighted.

Column	Maxgrp	Observed Indicator Value (IV)	IV from randomized groups Mean	S.Dev	p *
1 Ancylida	2002	23.9	22.7	9.84	0.3937
2 Arrenuri	2002	24.5	22.8	9.99	0.3663
3 Asellida	2002	26.5	31.2	11.35	0.5871
4 Baetidae	2002	7.2	16.5	9.17	0.9130
5 Caenidae	2002	47.4	41.3	7.33	0.1978
6 Ceratopo	2002	42.9	39.0	7.75	0.2769
7 Chironom	2002	50.4	38.4	2.78	0.0002
8 Coenagri	2002	52.3	35.8	7.81	0.0374
9 Corixida	2015	37.5	18.4	8.99	0.0892
10 Crangony	2002	31.4	18.5	9.12	0.1624
11 Dreissen	2010	16.2	19.5	10.13	0.4813
12 Elmidae	2002	29.1	29.7	10.35	0.4381
13 Enchytra	2002	17.0	18.7	8.97	0.4833
14 Ephydrid	2010	18.5	18.4	8.70	0.4153
15 Gammarid	2002	43.0	32.6	10.00	0.1456
16 Glossiph	2015	21.5	29.6	8.95	0.8292
17 Hyalelli	2002	57.7	36.4	8.17	0.0204
18 Hydridae	2002	36.6	22.1	9.89	0.1100
19 Hydrobii	2010	29.5	32.5	9.81	0.5611
20 Hydrodro	2015	17.4	23.6	9.15	0.7435
21 Hydrophi	2002	24.0	19.1	8.55	0.3671
22 Hydropti	2015	23.7	34.3	9.02	0.9250
23 Leptocer	2002	46.5	37.3	10.83	0.1786
24 Limnesii	2015	21.0	31.7	9.17	0.9290
25 Naididae	2002	45.3	38.8	3.00	0.0314
26 Physidae	2002	41.9	31.4	12.02	0.1878
27 Pionidae	2002	41.4	25.7	10.74	0.1056
28 Pisidiid	2010	31.0	38.5	8.61	0.8052
29 Plagiost	2002	73.8	26.4	10.25	0.0014
30 Planarii	2002	49.6	23.8	9.65	0.0236
31 Planorbi	2002	51.0	30.3	10.71	0.0526
32 Polycent	2002	45.4	22.8	9.91	0.0326
33 Pyralida	2002	28.8	18.4	8.89	0.1524
34 Tabanida	2002	35.2	21.5	10.46	0.1094
35 Tetraste	2002	25.1	23.5	10.47	0.3843
36 Trochoch	2002	37.5	16.4	8.81	0.0834
37 Valvatid	2015	25.3	23.5	10.28	0.4803
Averages		34.5187	27.32	9.18	0.3271

* proportion of randomized trials with indicator value
equal to or exceeding the observed indicator value.
p = (1 + number of runs >= observed)/(1 + number of randomized runs)
Maxgrp = Group identifier for group with maximum observed IV

Randomization test for sum of IVmax
1277.2 = observed sum of IVmax across all Families
14 = number of randomization runs with sum of IVmax >= observed value
4999 = number of randomization runs
0.00300 = p

APPENDIX F

Results of correlation with nonmetric multidimensional scaling axes – toxicity data

Table F1. Correlation of toxicity endpoints with individual NMS axes 1 and 2 using 2002, 2010, & 2015 time series data. Column data were relativized by maximum (N= 31 data points).

PC-ORD 6.19

Pearson and Kendall Correlations with Ordination Axes N= 31

Axis:	1			2		
	r	r-sq	tau	r	r-sq	tau
Crgw	.625	.391	.427	-.117	.014	-.093
Crsu	.665	.442	.264	.095	.009	-.015
Hagw	.499	.249	.369	.087	.008	.067
Hasu	.624	.389	.483	.034	.001	.039
Hlgw	.852	.727	.784	-.027	.001	-.069
Hlsu	.939	.881	.629	.122	.015	.216
Ttcc	.807	.652	.328	-.039	.002	-.007
Tthtch	.020	.000	.011	-.930	.865	-.729
Ttsu	.499	.249	-.018	-.413	.170	-.313
Ttyg	.643	.413	.280	-.248	.062	-.211

Table F2. Correlation of environmental variables with individual NMS axes 1 and 2 using 2002, 2010, & 2015 time series data. Data were log- or arcsine square root-transformed. (N= 31 data points)

PC-ORD 6.19

Pearson and Kendall Correlations with Ordination Axes N= 31

Axis:	1			2		
	r	r-sq	tau	r	r-sq	tau
Alkalini	.184	.034	.176	.308	.095	.145
NO2+NO3	-.212	.045	-.175	.174	.030	.084
TKN (mg/	.225	.051	.123	.371	.137	.278
TP(mg/L)	.334	.111	.191	.067	.004	.011
%Sand	.148	.022	.080	-.090	.008	-.118
SD-Ag (p	-.560	.313	-.390	-.187	.035	-.106
SD-Al2O3	.328	.108	.147	.143	.020	.091
As (ppm)	-.626	.391	-.398	-.278	.077	-.216
Cd (ppm)	-.455	.207	-.219	.390	.152	.277
Co (ppm)	-.394	.155	-.141	.111	.012	.106
Cr (ppm)	-.648	.419	-.433	-.156	.024	-.078
Cu (ppm)	-.684	.468	-.416	-.234	.055	-.157
Fe (ppm)	-.492	.242	-.250	-.338	.114	-.185
Hg (ppm)	-.526	.277	-.328	-.268	.072	-.198
Mn (ppm)	-.114	.013	.009	-.022	.000	-.022
Ni (ppm)	-.682	.465	-.415	-.169	.029	-.121
Pb (ppm)	-.714	.510	-.470	-.088	.008	-.041
Zn (ppm)	-.668	.446	-.422	-.283	.080	-.194
TOC (%)	-.094	.009	-.140	-.019	.000	.054
N-TKN (p	.034	.001	-.146	.016	.000	.065
TP (ppm)	-.482	.233	-.338	-.365	.133	-.213
SD-BaO (	.204	.042	.277	-.149	.022	-.020
SD-Be (p	.106	.011	-.037	-.092	.009	-.019
SD-CaO (	-.332	.110	-.099	-.035	.001	-.022
SD-Cr2O3	-.527	.277	-.358	-.335	.113	-.157
SD-Fe2O3	-.459	.211	-.250	-.361	.131	-.164
SD-K2O (	.242	.058	.044	-.013	.000	.004
SD-LOI (	-.309	.096	-.256	.063	.004	.045
SD-MgO (	.013	.000	.050	.174	.030	.075
SD-MnO (	.113	.013	.079	-.297	.088	-.335
SD-Na (p	-.150	.023	-.054	.725	.526	.502
SD-SiO2	.340	.116	.148	.216	.046	.123
SD-Sr (p	-.377	.142	-.211	.075	.006	.082
SD-TiO2	.330	.109	.169	.051	.003	-.022
SD-V (pp	.174	.030	.224	-.359	.129	-.241
SD-Y (pp	-.051	.003	-.028	.362	.131	.223
TPAHs (s	-.546	.298	-.256	-.537	.288	-.321
TPCB con	-.594	.353	-.355	-.454	.206	-.303
TEQs PCB	-.520	.271	-.344	-.434	.189	-.253