Targeted sampling of *Toxolasma parvum* (Lilliput) in southwestern Ontario, 2022

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Toxolasma parvum (Lilliput) is currently listed as Endangered under the federal *Species at Risk Act* (SARA). At the time of its previous assessment by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), only 39 live collections of *T. parvum* had ever been found in Canada. We hypothesized that the low detection of *T. parvum* may be the result of a failure to target preferred habitat types of this species in Canada. In 2022, Fisheries and Oceans Canada (DFO) initiated a sampling program to target Lilliput preferred habitats by sampling 28 sites in the Lake St. Clair watershed, 5 sites in the Lake Erie watershed, and 2 sites in the Lake Ontario watershed. A semi-quantitative timed-search survey was conducted at each site by a three- to five-person team for a 4.5 person-hour effort. In the Lake St. Clair watershed, 55 live *T. parvum* were detected, with presence at 50% of sites sampled and at 83.3% of waterbodies. *Toxolasma parvum* was not found live or as shells at any sites surveyed in the Lake Erie watershed or Lake Ontario watershed. These data provide updated information for the assessment of *T. parvum* by COSEWIC.

RÉSUMÉ

Gibson, M.P., McNichols-O'Rourke, K.A., and Morris, T.J. 2023. Targeted sampling of *Toxolasma parvum* (Lilliput) in southwestern Ontario, 2022. Can. Data Rep. Fish. Aquat. Sci. 1369: vi + 29 p.

Le toxolasme nain (*Toxolasma parvum*) est actuellement inscrit sur la liste des espèces en voie de disparition de la *Loi sur les espèces en péril* (LEP). Au moment de sa précédente évaluation par le Comité sur la situation des espèces en péril au Canada (COSEPAC), seulement 39 individus vivants de *T. parvum* avaient été observés au Canada. Nous avons émis l'hypothèse que la faible détection de *T. parvum* pourrait être le résultat d'un mauvais ciblage des types d'habitats privilégiés de cette espèce au Canada. En 2022, Pêches et Océans Canada (MPO) a lancé un programme d'échantillonnage dans le but de cibler les habitats privilégiés du toxolasme nain et a échantillonné 28 sites dans le bassin hydrographique du lac Sainte-Claire, 5 sites dans le bassin hydrographique du lac Érié et 2 sites dans le bassin hydrographique du lac Ontario. Une équipe de trois à cinq personnes a réalisé un relevé semi-quantitatif à intervalles réguliers sur chaque site, pour un effort de 4,5 heures-personnes. Dans le bassin hydrographique du lac Sainte-Claire, on a détecté 55 *T. Parvum* vivants, et on a observé une présence dans 50 % des sites échantillonnés et dans 83,3 % des plans d'eau. Aucun toxolasme nain vivant ou sous forme de coquille n'a été trouvé dans les sites ayant fait l'objet d'un relevé dans les bassins hydrographiques des lacs Érié et Ontario. Ces données fournissent des renseignements à jour pour l'évaluation de *T. Parvum* par le COSEPAC.

INTRODUCTION

Freshwater mussels are one of the most endangered taxa globally (Haag 2012). It is estimated that 33% of the Unionidae are threatened under the International Union for Conservation of Nature (IUCN) criteria (Böhm et al. 2021). In Canada, 38% of the 55 native freshwater mussel species have been assessed as at-risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Government of Canada 2021). The major threats contributing to their decline include habitat degradation by pollution, siltation, channelization, and impoundment as well as the invasion of species such as dreissenid mussels (*Dreissena polymorpha*, Zebra Mussel; *D. rostriformis bugensis*, Quagga Mussel) and *Neogobius melanostomus* (Round Goby) (Williams et al. 1992; Ricciardi et al. 1998; Lopes-Lima et al. 2018; Clark et al. 2022). Freshwater mussels play a crucial ecological role in aquatic ecosystems as ecosystem engineers (Haag 2012). They filter large volumes of water, promote nutrient cycling between pelagic and benthic foodwebs, and provide habitat for other organisms (Haag 2012). While many species share broad habitat tolerances and occupy dense species-rich aggregations, some species have specialized habitat preferences that produce unique and sometimes isolated distributions (Haag 2012). Accurately assessing and monitoring these species requires targeted sampling in these specialized habitats as they can go undetected during most general mussel surveys (Ortmann 1919; Metcalfe-Smith et al. 2007).

Toxolasma parvum (Lilliput) was assessed as Endangered by COSEWIC in 2013 based on 35 records representing 40 live individuals (COSEWIC 2013). It was listed as such on Schedule 1 of *Species at Risk Act* (SARA) in 2019 (Government of Canada 2021). *Toxolasma parvum* is a short-lived (Haag 2012), relatively small freshwater mussel; adults usually reach 25 mm in length and the maximum length in Canada is 54.8 mm (Fisheries and Oceans Canada, unpublished data). The species' habitat is known to be waterbodies with little current such as larger rivers, wetlands, and backwaters (Metcalfe-Smith et al. 2005) and it generally occurs in softer substrates such as muck, detritus, sand, silt, and clay (Metcalfe-Smith et al. 2005; COSEWIC 2013). These habitat types have been undersampled in Canada; thus, some populations may have gone undetected (Fisheries and Oceans Canada 2022). For this reason, targeted surveys were considered necessary to accurately define the Canadian range and distribution of *T. parvum*. Data outlined in this report aim to address two recovery measures identified in the Recovery Strategy and Action Plan for *T. parvum* by confirming the persistence of currently known populations and discovering new populations (Fisheries and Oceans Canada 2022). These data will provide updated information for COSEWIC to assess the status of *T. parvum* in Canada (Fisheries and Oceans Canada 2022).

METHODS

SITE SELECTION

Sites were selected based on the presence of live *T*. *parvum* or shells during previous surveys or based on the presence of the preferred habitat type of the species. In 2010, *T*. *parvum* was found live in the Belle and Ruscom rivers and Baptiste Creek (McNichols et al. 2012); therefore, these sites were revisited to determine the distribution within these systems. In addition, creeks and rivers found along the south shore of Lake St. Clair, north shore of Lake Erie, and in Spencer Creek (Lake Ontario drainage) were also explored. These included waterbodies where surveys had not been previously conducted but were within close proximity to other sites or waterbodies with *T*. *parvum* present. Sites were sampled based on accessibility, the presence of preferred habitat, and to ensure a representative distribution of sites within individual tributaries and throughout the greater watershed.

FRESHWATER MUSSEL SAMPLING

A semi-quantitative timed-search survey was conducted by a three- to five-person crew for a total of 4.5 person-hours at each site (Metcalfe-Smith et al. 2000). Crew members used long-handled mussel scoops (7 mm mesh) or tactile searching based on the depth of a site. Live individuals and shells of all mussel species found during the search time were collected in dive bags and processed at the end of the sampling period. All live mussels were identified to species, measured (maximum length in millimeters) using calipers, and sexed (if sexually dimorphic) before being returned to the waterbody. Individual *T*. *parvum* were classified as either adult or juvenile based on the measured shell length. Following the methods of Haag (2012) and using a length-at-age dataset collected for *T. parvum* from Hamilton Harbour (Fisheries and Oceans Canada, unpublished data), individuals less than 15 mm in maximum length were considered juveniles.

In addition, shells of species not found live at the site were identified to species, enumerated, and shell condition was recorded (whole shell or valve, fresh or weathered). Partial valves or shell fragments were recorded as weathered valves and were identified to species when possible. All shells of *T. parvum* were kept as vouchers. Digital vouchers were taken of each species found following Morris et al. (2022).

ENVIRONMENTAL DATA COLLECTION

At each site, before conducting the timed-search survey, air temperature and wind speed were recorded using a Kestrel 2000 Pocket Wind Meter, water velocity was measured using an OTT MF Pro flow meter, water clarity was assessed using a 0.60 m turbidity tube, and water temperature and chemistry were measured using an EXO2 Multiparameter YSI. After the timed-search, substrate composition was qualitatively assessed and recorded as percentages of the total substrate at the site. Substrate sizes were modified from Stanfield (2010) and defined as: bedrock, boulder (>250 mm in diameter), cobble (65–250 mm), gravel (2–65 mm), sand (grainy, 0.06–2 mm), silt

(floury, <0.06mm), clay, muck (soft substrate), and detritus (plant matter). In addition, stream morphology was assessed and recorded as percentages; these include riffle, run, and pool, defined in Fuller (2018), and flat (shallow to moderately deep, low water velocity, no turbulence). Dimensions of the river were measured using a Nikon Laser 1200S waterproof laser range finder and included length of river reach searched and the minimum, maximum, and average river width at the site. The minimum and maximum depth searched was measured using a metre stick.

DATA VISUALIZATION

Figures and maps were created in R (R Core Team 2022; RStudio Team 2022) using the ggplot2 package (Wickham 2016). Additional packages used for creating maps were cowplot (Wilke 2020), ggrepel (Slowikowski 2023), ggspatial (Dunnington 2022), maptiles (Giraud 2022), sf (Pebesma 2018), terra (Hijmans 2022), and tidyterra (Hernangomez 2022).

RESULTS

Freshwater mussel surveys were conducted from June to August 2022 at 35 sites across all watersheds sampled (Table 1). An additional 12 sites were scouted but not sampled (Table 2). A total of 317 mussels were observed representing 11 species, including two species at risk (SAR): *T. parvum* and *Quadrula quadrula* (Mapleleaf) (Table 3; Table 4).

LAKE ST. CLAIR WATERSHED

In the Lake St. Clair watershed, a total of 300 mussels were observed representing 11 species, including two SAR at 28 sites (Table 3). Fifty-five live *T. parvum* were found at 14 of 28 sites (50%) surveyed (Figure 1, Table 5). Shells and/or partial shells were collected from five additional sites resulting in *T. parvum* detections at 19 of 28 sites (68%) (Table 5). Thus, *T. parvum* was found live at 10 of the 12 (83.3%) waterbodies sampled in this region and was detected at 11 of the 12 (91.7%) waterbodies sampled. The average length was 16.83 ± 1.28 mm and ranged from 6.6-38.2 mm (Figure 2; Table 5). Thirty-two individuals were considered juveniles, with 22 of these individuals found at one site, LSC-MSO-01, in an inlet off of Moison Creek. This site also had the highest number of *T*. *parvum* (24 individuals) found throughout the surveys; all other sites where *T*. *parvum* was found live yielded 1 to 4 individuals (Table 5). *Toxolasma parvum* represented the most abundant mussel species at 5 of 14 (35.7%) sites where it was found live (Table 3) with a median (± standard error) of 3 ± 1.6 live individuals/site. This yields a mean site catch per unit effort (CPUE; ± standard error) of 0.44 ± 0.19 mussels/hour for this watershed.

Throughout the surveys, six other species were found at the same sites as *T. parvum* (Table 3). The most common species found at sites where *T. parvum* was found live were *Utterbackia imbecillis* (Paper Pondshell) and *Pyganodon grandis* (Giant Floater). Interestingly, *U. imbecillis* was the most abundant at 7 of 14 (50%) sites where

T. parvum was found live whereas *P. grandis* was the most abundant species at just 1 of 14 sites (0.07%) where *T. parvum* was found live.

Quadrula quadrula, a species of Special Concern (Government of Canada 2021), was found at 6 of 28 (21.4%) sites and in 5 of 12 (41.7%) waterbodies. Thirty-five live individuals were found across all sites. The species was dominant at 2 of 28 (0.07%) sites. *Toxolasma parvum* and *Q. quadrula* were found live together at 3 of 28 (10.7%) sites.

Stream morphology (Figure 3) and substrate (Figure 4) differed between sites where *T. parvum* was detected (live or as shells) and not detected. Sites with *T. parvum* detection were comprised of averages (± standard error) of 49 ± 11.26% flat and 33 ± 10.84% pool habitat, whereas sites without *T. parvum* contained an average of 54 ± 12.21% run habitat (Figure 3). Substrate at sites with *T. parvum* detection had a mean of 49 ± 5.24% muck and 21 ± 3.33% detritus and sites without contained mean substrate compositions of 30 ± 7.00% muck, 22 ± 7.13% clay, and 19 ± 6.51% sand (Figure 4). Relevant habitat data can be found in Table 6.

LAKE ERIE WATERSHED

Five sites in five different waterbodies were sampled in the Lake Erie watershed (Figure 5). A total of 17 mussels representing three species were found including one SAR (Table 4). No evidence of *T. parvum* was found. The most abundant species was *P. grandis*; 14 individuals were found at 2 sites. *Quadrula quadrula* was found at one site on Sandusk Creek, LER-SDK-01. Relevant habitat data can be found in Table 7.

LAKE ONTARIO WATERSHED

No mussels were found at either of the two sites sampled (Figure 6) in Spencer Creek in the Lake Ontario watershed; however, *T. parvum* is known to occur in the area (Richer and Theijsemeijer 2017; Wright et al. 2020; Lower Great Lakes Unionid Database 2022). The only evidence of mussel presence was a single, weathered, unidentifiable shell fragment at one of the sites. Relevant habitat data can be found in Table 8.

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Table 1. Site locations and sample dates for sites sampled in the Lake St. Clair, Lake Erie, and Lake Ontario watersheds in 2022. Highlighted sites were originally sampled in 2010, all other sites were previously unsampled. Sites without public access marked with an asterisk.

Site Code	Drainage	Waterbody	Latitude	Longitude	Date
LSC-BAP-02	Lake St. Clair	Baptiste Creek	42.305403	-82.435649	24-Aug-2022
TR-55	Lake St. Clair	Baptiste Creek	42.28785	-82.41109	18-Jul-2022
LSC-BLR-01	Lake St. Clair	Belle River	42.16401	-82.72757	28-Jun-2022
LSC-BLR-02	Lake St. Clair	Belle River	42.20271	-82.72058	29-Jun-2022
LSC-BLR-03	Lake St. Clair	Belle River	42.25112	-82.71449	28-Jun-2022
LSC-BLR-13	Lake St. Clair	Belle River	42.272778	-82.715592	28-Jun-2022
LSC-BGC-01	Lake St. Clair	Big Creek	42.276633	-82.4645	11-Aug-2022
LSC-BOD-01	Lake St. Clair	Boda's Lake	42.288524	-82.687397	22-Aug-2022
LSC-DUC-01	Lake St. Clair	Duck Creek	42.292344	-82.687112	5-Aug-2022
LSC-JEA-01	Lake St. Clair	Jeannette’s Creek	42.324877	-82.330013	24-Aug-2022
LSC-JEA-02	Lake St. Clair	Jeannette’s Creek	42.324716	-82.397899	24-Aug-2022
LSC-LTC-01	Lake St. Clair	Little Creek	42.30548	-82.51122	23-Aug-2022
LSC-MSO-01*	Lake St. Clair	Moison Creek	42.297598	-82.664345	10-Aug-2022
LSC-PKC-01	Lake St. Clair	Pike Creek	42.3044619	-82.843059	4-Aug-2022
LSC-PKC-02	Lake St. Clair	Pike Creek	42.293313	-82.845412	4-Aug-2022
LSC-PCR-02	Lake St. Clair	Puce River	42.297064	-82.783576	15-Jun-2022
LSC-PCR-03*	Lake St. Clair	Puce River	42.295942	-82.782318	15-Jun-2022
LSC-PCR-04*	Lake St. Clair	Puce River	42.286055	-82.781277	4-Aug-2022
LSC-PCR-05*	Lake St. Clair	Puce River	42.290212	-82.783726	23-Aug-2022
RS-02	Lake St. Clair	Ruscom River	42.18117	-82.65369	8-Jun-2022
RS-03*	Lake St. Clair	Ruscom River	42.21993	-82.62143	8-Jun-2022
RS-05	Lake St. Clair	Ruscom River	42.30214	-82.6213	29-Jun-2022
RS-06	Lake St. Clair	Ruscom River	42.27139	-82.62832	27-Jun-2022
LSC-RUS-07	Lake St. Clair	Ruscom River	42.24354	-82.614373	14-Jun-2022
LSC-RUS-08	Lake St. Clair	Ruscom River	42.172616	-82.664458	14-Jun-2022
LSC-RUS-09	Lake St. Clair	Ruscom River	42.19217	-82.63632	29-Jun-2022
LSC-TIL-01	Lake St. Clair	Tilbury Creek	42.290423	-82.452014	23-Aug-2022
LSC-TIL-02	Lake St. Clair	Tilbury Creek	42.263815	-82.449205	25-Aug-2022
LER-EVC-01	Lake Erie	Evans Creek	42.84417	-79.76004	29-Aug-2022
LER-LYN-01	Lake Erie	Lynn River	42.79186	-80.203082	30-Aug-2022
LER-SDK-01	Lake Erie	Sandusk Creek	42.823639	-79.993915	29-Aug-2022
LER-STO-01	Lake Erie	Stoney Creek	42.8188	-79.9264	14-Jul-2022
LER-WDC-01	Lake Erie	Wardell Creek	42.845379	-79.774845	29-Aug-2022
LON-SPC-04	Lake Ontario	Spencer Creek	43.27001	-79.92657	2-Jun-2022
LON-SPC-05	Lake Ontario	Spencer Creek	43.27256	-79.92519	2-Jun-2022

Table 2. Location and dates for sites scouted but not sampled due to insufficient access or unsuitable habitat in the Lake St. Clair, Lake Erie, and Lake Ontario watersheds in 2022. Highlighted sites were previously sampled in 2010, all other sites were previously unsampled.

Site Code	Drainage	Waterbody	Latitude	Longitude	Date	Site Condition
	Lake St. Clair	Baptiste Creek	42.28130	-82.39621	14-Jun-22	Too deep
	Lake St. Clair	Big Creek	42.288996	-82.46272	11-Aug-22	Unsafe conditions
	Lake St. Clair	Duck Creek	42.273304	-82.68894	22-Aug-22	Unsuitable habitat; narrow stream and boulder substrate
	Lake St. Clair	Little Creek	42.29708	-82.51428	23-Aug-22	Too deep
	Lake St. Clair	Pike Creek	42.31356	-82.84301	4-Aug-22	Not accessible; no parking
	Lake St. Clair	Pike Creek	42.293207	-82.83794	4-Aug-22	Unsuitable habitat; narrow stream with artificial structures
	Lake St. Clair	Pike Creek	42.309614	-82.844309	4-Aug-22	Not accessible; posted “no trespassing”
	Lake St. Clair	Pike Creek	42.31557	-82.840971	4-Aug-22	Not accessible; no parking
	Lake St. Clair	Puce River	42.27747	-82.788816	4-Aug-22	Unsuitable habitat; riprap and sand substrate
RS-01	Lake St. Clair	Ruscom River	42.13716	-82.6725	8-Jun-22	Unsuitable habitat; narrow stream
RS-02	Lake St. Clair	Ruscom River	42.25045	-82.61957	8-Jun-22	Unsafe conditions
	Lake St. Clair	Tilbury Creek	42.276014	-82.44754	25-Aug-22	Too deep
	Lake Erie	Gates Creek	42.834985	-79.819889	29-Aug-22	Too deep
	Lake Erie	Hickory Creek	42.8075373	-80.023599	30-Aug-22	Unsuitable habitat; algal mats and sand substrate

Table 3. Species detected at sites in the Lake St. Clair watershed. Total abundance, *Toxolasma parvum* (Lilliput) Relative Abundance, live species richness, and dominant species at each site. Species at risk are highlighted. Sites with shells, valves, and/or shell fragments but no live specimens are indicated with SH.

Waterbody	**Baptiste Creek**	**Baptiste Creek**	**Belle River**	**Belle River**	**Belle River**	**Belle River**	**Big Creek**
Site Code	**LSC-BAP-02**	**TR-55**	**LSC-BLR-01**	**LSC-BLR-02**	**LSC-BLR-03**	**LSC-BLR-13**	**LSC-BGC-01**
Anodontoides ferussacianus	0	0	0	0	0	0	0
Lampsilis cardium	0	0	0	0	0	0	0
Lampsilis siliquoidea	0	0	0	0	0	0	0
Lasmigona complanata	0	0	0	SH	30	0	0
Potamilus alatus	0	0	0	0	0	0	0
Potamilus fragilis	0	0	0	0	0	0	0
Pyganodon grandis	1	1	0	SH	13	1	1
Quadrula quadrula	0	11	0	0	4	0	0
Strophitus undulatus	0	0	0	0	0	0	0
Toxolasma parvum	3	0	0	0	3	3	0
Truncilla truncata	0	1	0	0	0	0	0
Utterbackia imbecillis	2	4	0	0	0	0	4
Total Abundance	**6**	**17**	**0**	**0**	**50**	**4**	**5**
***T. parvum* Relative Abundance**	**0.50**	**0**	**0**	**0**	**0.06**	**0.75**	**0**
Live Species Richness	**3**	**4**	**0**	**0**	**4**	**2**	**2**
Dominant Species	***T. parvum***	***Q. quadrula***			***L. complanata***	***T. parvum***	***U. imbecillis***

Table 3. (Continued) Species detected at sites in the Lake St. Clair watershed. Total abundance, *Toxolasma parvum* (Lilliput) Relative Abundance, live species richness, and dominant species at each site. Species at risk are highlighted. Sites with shells, valves, and/or shell fragments but no live specimens are indicated with SH.

Waterbody	**Boda's Lake**	**Duck Creek**	**Jeannette's Creek**	**Jeannette's Creek**	**Little Creek**	**Moison Creek**	**Pike Creek**
Site Code	**LSC-BOD-01**	**LSC-DUC-01**	**LSC-JEA-01**	**LSC-JEA-02**	**LSC-LTC-01**	**LSC-MSO-01**	**LSC-PKC-01**
Anodontoides ferussacianus	0	0	0	0	0	0	0
Lampsilis cardium	0	0	0	0	0	0	0
Lampsilis siliquoidea	0	0	0	0	0	0	0
Lasmigona complanata	0	0	0	0	0	0	0
Potamilus alatus	0	0	0	0	0	0	0
Potamilus fragilis	0	0	0	0	0	0	0
Pyganodon grandis	3	0	SH	1	0	11	2
Quadrula quadrula	0	0	1	0	0	0	0
Strophitus undulatus	0	0	0	0	0	0	0
Toxolasma parvum	SH	2	1	3	1	24	4
Truncilla truncata	0	0	0	0	0	0	0
Utterbackia imbecillis	0	15	2	3	2	13	9
Total Abundance	**3**	**17**	**4**	**7**	**3**	**48**	**15**
***T. parvum* Relative Abundance**	**0**	**0.12**	**0.25**	**0.43**	**0.33**	**0.50**	**0.27**
Live Species Richness	**1**	**2**	**3**	**3**	**2**	**3**	**3**
Dominant Species	***P. grandis***	***U. imbecillis***	***U. imbecillis***	***T. parvum* & *U. imbecillis***	***U. imbecillis***	***T. parvum***	***U. imbecillis***

Table 3. (Continued) Species detected at sites in the Lake St. Clair watershed. Total abundance, *Toxolasma parvum* (Lilliput) Relative Abundance, live species richness, and dominant species at each site. Species at risk are highlighted. Sites with shells, valves, and/or shell fragments but no live specimens are indicated with SH.

Waterbody	**Pike Creek**	**Puce River**	**Puce River**	**Puce River**	**Puce River**	**Ruscom River**	**Ruscom River**
Site Code	**LSC-PKC-02**	**LSC-PCR-02**	**LSC-PCR-03**	**LSC-PCR-04**	**LSC-PCR-05**	**RS-02**	**RS-03**
Anodontoides ferussacianus	0	0	0	0	0	SH	0
Lampsilis cardium	0	0	0	0	0	0	0
Lampsilis siliquoidea	0	0	1	0	0	2	3
Lasmigona complanata	0	0	2	0	0	11	2
Potamilus alatus	0	0	SH	0	0	0	0
Potamilus fragilis	0	0	3	1	0	0	0
Pyganodon grandis	2	8	8	4	0	3	0
Quadrula quadrula	0	SH	7	0	0	0	3
Strophitus undulatus	0	0	0	0	0	0	0
Toxolasma parvum	SH	SH	4	2	3	SH	0
Truncilla truncata	0	0	0	0	0	0	0
Utterbackia imbecillis	1	1	3	7	2	0	0
Total Abundance	**3**	**9**	**28**	**14**	**5**	**16**	**8**
***T. parvum* Relative Abundance**	**0**	**0**	**0.14**	**0.14**	**0.60**	**0**	**0**
Live Species Richness	**2**	**2**	**8**	**4**	**2**	**3**	**3**
Dominant Species	***P. grandis***	***P. grandis***	***P. grandis***	***U. imbecillis***	***T. parvum***	***L. complanata***	***L. siliquoidea* & *Q. Quadrula***

Table 3. (Continued) Species detected at sites in the Lake St. Clair watershed. Total abundance, *Toxolasma parvum* (Lilliput) Relative Abundance, live species richness, and dominant species at each site. Species at risk are highlighted. Sites with shells, valves, and/or shell fragments but no live specimens are indicated with SH.

Waterbody	**Ruscom River**	**Ruscom River**	**Ruscom River**	**Ruscom River**	**Ruscom River**	**Tilbury Creek**	**Tilbury Creek**
Site Code	**RS-05**	**RS-06**	**LSC-RUS-07**	**LSC-RUS-08**	**LSC-RUS-09**	**LSC-TIL-01**	**LSC-TIL-02**
Anodontoides ferussacianus	0	0	0	SH	0	0	0
Lampsilis cardium	0	0	1	0	0	0	0
Lampsilis siliquoidea	0	2	2	0	1	0	0
Lasmigona complanata	0	0	SH	0	3	0	0
Potamilus alatus	1	0	0	0	0	0	0
Potamilus fragilis	0	2	0	0	0	0	0
Pyganodon grandis	0	2	SH	SH	4	1	SH
Quadrula quadrula	0	SH	9	0	0	0	0
Strophitus undulatus	0	0	0	0	1	0	0
Toxolasma parvum	0	1	0	0	0	1	SH
Truncilla truncata	0	SH	0	0	0	0	0
Utterbackia imbecillis	0	3	0	0	0	4	SH
Total Abundance	**1**	**10**	**12**	**0**	**9**	**6**	**0**
***T. parvum* Relative Abundance**	**0**	**0.10**	**0**	**0**	**0**	**0.17**	**0**
Live Species Richness	**1**	**5**	**3**	**0**	**4**	**3**	**0**
Dominant Species	***P. alatus***	***U. imbecillis***	***Q. quadrula***		***P. grandis***	***U. imbecillis***	

Table 4. Species detected at sites in the Lake Erie watershed. Total abundance, live species richness, and dominant species at each site. Species at risk are highlighted. Sites with shells, valves, and/or shell fragments but no live specimens are indicated with SH.

Waterbody	**Evan's Creek**	**Lynn River**	**Sandusk Creek**	**Stoney Creek**	**Wardell Creek**
Site Code	**LER-EVC-01**	**LER-LYN-01**	**LER-SDK-01**	**LER-STO-01**	**LER-WDC-01**
Pyganodon grandis	7	0	0	7	SH
Quadrula quadrula	0	0	2	0	0
Utterbackia imbecillis	1	0	0	0	0
Total Abundance	**8**	**0**	**2**	**7**	**0**
Live Species Richness	**2**	**0**	**1**	**1**	**0**
Dominant Species	***P. grandis***		***Q. quadrula***	***P. grandis***	

Table 5. Counts and sizes of live *Toxolasma parvum* (Lilliput) and counts of shells of varying conditions found during freshwater mussel surveys in the Lake St. Clair watershed at sites where *T. parvum* was detected. Highlighted sites are where only shells were found.

Site Code	Waterbody	Live	Sizes (mm)	Fresh Whole Shells	Fresh Valves	Weathered Whole Shells	Weathered Valves & Fragments
LSC-BAP-02	Baptiste Creek	3	10.5 - 13.2	0	0	0	0
LSC-BLR-03	Belle River	3	26.5 - 32	0	1	0	0
LSC-BLR-13	Belle River	3	12.8 - 38.2	0	0	0	0
LSC-BOD-01	Boda's Lake	0		0	0	0	2
LSC-DUC-01	Duck Creek	2	34.7, 36.1	0	0	0	0
LSC-JEA-01	Jeannette's Creek	1	9.9	0	0	0	0
LSC-JEA-02	Jeannette's Creek	3	7.1 - 15.2	0	0	0	1
LSC-LTC-01	Little Creek	1	24.0	0	0	0	0
LSC-MSO-01	Moison Creek	24	6.6 - 15.5	0	0	1	0
LSC-PKC-01	Pike Creek	4	23.3 - 27.2	1	0	0	0
LSC-PKC-02	Pike Creek	0		0	0	0	1
LSC-PCR-02	Puce River	0		0	0	0	1
LSC-PCR-03	Puce River	4	8.9 - 33	0	0	0	1
LSC-PCR-04	Puce River	2	20.8, 21.6	0	0	0	0
LSC-PCR-05	Puce River	3	12.5 - 28.1	0	0	0	0
RS-02	Ruscom River	0		2	0	0	0
RS-06	Ruscom River	1	31.0	0	0	0	0
LSC-TIL-01	Tilbury Creek	1	35.6	0	0	0	0
LSC-TIL-02	Tilbury Creek	0		0	0	0	3

Table 6. Environmental data collected at each site in the Lake St. Clair watershed.

Site Details	**Site Code**	**LSC-BAP-02**	**TR-55**	**LSC-BLR01**	**LSC-BLR-02**	**LSC-BLR-03**	**LSC-BLR-13**
	Waterbody	**Baptiste Creek**	**Baptiste Creek**	**Belle River**	**Belle River**	**Belle River**	**Belle River**
	***T. parvum* Presence**	Live	Not Detected	Not Detected	Not Detected	Live	Live
Search Area Measurements	**Length of Reach (m)**	22.5	69.0	108.5	118.5	103.5	89.0
	Min Width of Reach (m)	40	17	8	2	3	2
	Max Width of Reach (m)		20	10	10	11	8
	Avg Width (m)		18	9	8	10	6
	Max Depth Searched (m)	1.15	1.60	0.55	0.55	0.75	1.43
	Avg Depth Searched (m)	0.90	1.30	0.49	0.35	0.55	1.20
	Water Clarity (m)	0.08	0.17	0.05	0.09	0.10	0.20
	Water Velocity (m/s)	0	0.002	0.0003	0.006	0.008	0
	Stream Shading	Open	Open	Partly Open	Partly Open	Partly Open	Partly Open
	Algal Growth	Present	Present	Absent	Present	Present	Present
YSI Measurements	**Water Temperature (°C)**	24.82	28.16	18.16	19.25	18.70	26.62
	Conductivity (us/cm)	653.0	721.0	932.0	684.0	582.0	823.0
	ODO (%)	55.6	145.4	43.3	49.8	53.2	88.0
	ODO (mg/L)	4.60	11.37	4.06	4.52	4.95	7.30
	pH	7.83	8.49	7.82	7.73	7.76	7.92
	Salinity (psu)	0.32	0.33	0.53	0.38	0.32	0.39
	TDS (mg/L)	426.058	440.652	695.443	499.331	430.082	516.214
	Turbidity (FNU)	103.35	30.03	50.81	41.87	47.06	17.27
Stream Morphology	**Riffle (%)**	0	0	0	2	0	0
	Pool (%)	100	0	0	0	0	0
	Run (%)	0	100	0	98	0	0
	Flat (%)	0	0	100	0	100	100
Substrate Composition	**Bedrock (%)**	0	0	0	0	0	0
	Boulder (%)	0	0	0	0	0	0
	Rubble (%)	0	5	0	0	0	0
	Gravel (%)	0	5	5	35	0	0
	Sand (%)	0	5	25	35	30	10
	Silt (%)	0	0	5	5	0	30
	Clay (%)	10	5	30	5	20	0
	Muck (%)	50	50	25	10	40	30
	Detritus (%)	40	30	10	10	10	30
	Dreissenid Presence	Live	Shells Only	Not Detected	Not Detected	Not Detected	Not Detected

Table 6. (Continued) Environmental data collected at each site in the Lake St. Clair watershed.

Site Details	**Site Code**	**LSC-BGC-01**	**LSC-BOD-01**	**LSC-DUC-01**	**LSC-JEA-01**	**LSC-JEA-02**
	Waterbody	**Big Creek**	**Boda's Lake**	**Duck Creek**	**Jeannette's Creek**	**Jeannette's Creek**
	***T. parvum* Presence**	Not Detected	Shells Only	Live	Live	Live
Search Area Measurements	**Length of Reach (m)**	13.0	80.0	40.0	47.0	36.5
	Min Width of Reach (m)			20	46	67
	Max Width of Reach (m)	31	65	20	46	67
	Avg Width (m)			20	46	67
	Max Depth Searched (m)	1.13	1.00	1.10	1.10	0.85
	Avg Depth Searched (m)	0.72	0.80	1.00	0.86	0.70
	Water Clarity (m)	0.296	0.042	0.150	0.120	0.078
	Water Velocity (m/s)		0.007	0	0.001	0.01
	Stream Shading	Open	Open	Open	Open	Open
	Algal Growth	Present	Present	Present	Present	Present
YSI Measurements	**Water Temperature (°C)**	25.71	23.96	25.58	25.52	27.73
	Conductivity (us/cm)	693.0	724.0	539.0	500.0	677.0
	ODO (%)	37.5	63.6	37.7	94.2	128.7
	ODO (mg/L)	3.05	5.34	3.06	7.70	10.11
	pH	7.48	7.94	7.56	8.27	8.56
	Salinity (psu)	0.33	0.36	0.26	0.24	0.31
	TDS (mg/L)	444.355	480.5	346.512	321.973	418.329
	Turbidity (FNU)	10.70	125.49	21.25	36.34	21.35
Stream Morphology	**Riffle (%)**	0	0	0	0	0
	Pool (%)	100	100	0	0	0
	Run (%)	0	0	0	100	0
	Flat (%)	0	0	100	0	100
Substrate Composition	**Bedrock (%)**	0	0	0	0	0
	Boulder (%)	0	0	0	0	0
	Rubble (%)	0	5	5	0	0
	Gravel (%)	10	2	5	5	0
	Sand (%)	0	0	0	0	0
	Silt (%)	0	0	0	0	0
	Clay (%)	0	90	10	0	0
	Muck (%)	70	0	45	60	60
	Detritus (%)	20	3	35	35	40
	Dreissenid Presence	Live	Not Detected	Shells Only	Not Detected	Shells Only

Table 6. (Continued) Environmental data collected at each site in the Lake St. Clair watershed.

		Site Code	LSC-LTC-01	LSC-MSO-01	LSC-PKC-01	LSC-PKC-02	LSC-PCR-02	LSC-PCR-03
Site Details		Waterbody	Little Creek	Moison Creek	Pike Creek	Pike Creek	Puce River	Puce River
		T. parvum Presence	Live	Live	Live	Shells Only	Shells Only	Live
Search Area Measurements		Length of Reach (m)	20	60	20	100	84	34
		Min Width of Reach (m)	19	34	10	13	21	10
		Max Width of Reach (m)	19	34	15	16	21	10
		Avg Width (m)	19	34	11	14	21	10
		Max Depth Searched (m)	1.15	1.10	1.00	1.10	1.10	
		Avg Depth Searched (m)	0.75	0.88	0.79	0.95	0.80	
		Water Clarity (m)	0.19	0.302	0.225	0.195	0.08	0.11
		Water Velocity (m/s)	0.005	0.044	0	0.025	0.003	0.008
		Stream Shading	Partly Open	Open	Partly Open	Partly Open		Open
		Algal Growth	Present	Abundant	Present	Present		Absent
YSI Measurements		Water Temperature (°C)	24.59	28.90	25.54	23.75	24.73	25.94
		Conductivity (us/cm)	442.3	425.8	836.0	1038.0	651.0	694.0
		ODO (%)	55.7	128.3	43.5	26.7	42.2	37.1
		ODO (mg/L)	4.64	9.90	3.54	2.25	3.41	2.94
		pH	7.76	8.37	7.71	7.54	7.57	7.40
		Salinity (psu)	0.21	0.19	0.40	0.53	0.32	0.33
		TDS (mg/L)	289.000	257.658	537.927	691.497	431.651	442.556
		Turbidity (FNU)	20.00	15.79	14.98	18.00	134.62	8.62
Stream Morphology		Riffle (%)	0	0	0	0	0	0
		Pool (%)	0	100	100	0	100	0
		Run (%)	0	0	0	0	0	100
		Flat (%)	100	0	0	100	0	0
Substrate Composition		Bedrock (%)	0	0	0	0	0	0
		Boulder (%)	0	0	0	0	0	0
		Rubble (%)	0	5	0	0	0	0
		Gravel (%)	0	5	12	5	2	0
		Sand (%)	0	20	7	10	3	40
		Silt (%)	0	0	0	0	0	20
		Clay (%)	5	5	17	20	0	0
		Muck (%)	80	55	42	35	85	40
		Detritus (%)	15	10	22	30	10	0
		Dreissenid Presence	Live	Not Detected	Live	Live	Live	Shells Only

Table 6. (Continued) Environmental data collected at each site in the Lake St. Clair watershed.

		Site Code	LSC-PCR-04	LSC-PCR-05	RS-02	RS-03	RS-05
Site Details		Waterbody	Puce River	Puce River	Ruscom River	Ruscom River	Ruscom River
		T. parvum Presence	Live	Live	Shells Only	Not Detected	Not Detected
Search Area Measurements		Length of Reach (m)	95.0	48.0	105.5	33.0	79.5
		Min Width of Reach (m)	15	8	2	9	2
		Max Width of Reach (m)	18	10	4	9	10
		Avg Width (m)	17	8	3	9	8
		Max Depth Searched (m)	1.0	1.10	43.0	94.0	1. 5
		Avg Depth Searched (m)	0.5	0.7	38.0	70.0	1.2
		Water Clarity (m)	0.138	0.146	0.146	0.143	0.375
		Water Velocity (m/s)	0.002	0	0.101	0.039	
		Stream Shading	Open	Partly Open	Open	Partly Open	Open
		Algal Growth	Present	Present	Present	Present	Present
YSI Measurements		Water Temperature (°C)	25.46	22.30	17.08	18.39	23.43
		Conductivity (us/cm)	732.0	796.0	641.0	599.0	249.7
		ODO (%)	65.7	28.0	84.7	79.5	113.8
		ODO (mg/L)	5.36	2.44	8.15	7.42	9.69
		pH	7.81	7.58	7.98	7.80	8.85
		Salinity (psu)	0.35	0.41	0.37	0.34	0.12
		TDS (mg/L)	472.354	545.840	490.586	445.636	167.823
		Turbidity (FNU)	30.12	31.38	37.67	48.72	7.01
Stream Morphology		Riffle (%)	0	0	0	0	0
		Pool (%)	0	100	0	0	0
		Run (%)	0	0	100	100	0
		Flat (%)	100	0	0	0	100
Substrate Composition		Bedrock (%)	0	0	0	0	0
		Boulder (%)	0	0	0	0	0
		Rubble (%)	0	0	10	10	0
		Gravel (%)	5	3	20	15	5
		Sand (%)	5	0	20	10	95
		Silt (%)	0	0	10	5	0
		Clay (%)	35	0	20	30	0
		Muck (%)	45	87	15	10	0
		Detritus (%)	10	10	5	20	0
		Dreissenid Presence	Not Detected	Shells Only	Not Detected	Not Detected	Live

Table 6. (Continued) Environmental data collected at each site in the Lake St. Clair watershed.

Site Details	**Site Code**	**RS-06**	**LSC-RUS-07**	**LSC-RUS-08**	**LSC-RUS-09**	**LSC-TIL-01**	**LSC-TIL-02**
	Waterbody	**Ruscom River**	**Ruscom River**	**Ruscom River**	**Ruscom River**	**Tilbury Creek**	**Tilbury Creek**
	***T. parvum* Presence**	Live	Not Detected	Not Detected	Not Detected	Live	Shells Only
Search Area Measurements	**Length of Reach (m)**	53.5	140.0	237.5	160.0	32.0	15.0
	Min Width of Reach (m)	3	5	1	2	3	20
	Max Width of Reach (m)	8	5.5	5	5	30	20
	Avg Width (m)	4	5.5	3.5	3	4	20
	Max Depth Searched (m)	1.25	0.77	0.85	0.55	1.10	1.15
	Avg Depth Searched (m)	1.00	0.55	0.50	0.35	0.75	0.75
	Water Clarity (m)	0.12	0.096	0.153	0.098	0.22	0.198
	Water Velocity (m/s)	0.010	0.202	0.433	0.058	0.011	0.000
	Stream Shading	Open	Dense	Partly Open	Partly Open	Partly Open	Open
	Algal Growth	Absent	Absent	Present	Abundant	Present	Present
YSI Measurements	**Water Temperature (°C)**	25.45	22.87	23.39	20.42	27.03	24.10
	Conductivity (us/cm)	778.0	686.0	726.0	628.0	813.0	621.0
	ODO (%)	128.2	80.9	92.5	85.2	90.5	43.2
	ODO (mg/L)	10.46	6.94	7.86	7.66	7.17	3.63
	pH	8.4	8.02	8.14	7.93	8.07	7.49
	Salinity (psu)	0.38	0.35	0.37	0.34	0.38	0.31
	TDS (mg/L)	501.857	464.675	487.254	447.075	507.375	410.558
	Turbidity (FNU)	27.64	64.47	31.76	41.50	13.88	88.25
Stream Morphology	**Riffle (%)**	0	0	30	5	0	0
	Pool (%)	0	0	10	0	20	0
	Run (%)	50	100	60	95	0	0
	Flat (%)	50	0	0	0	80	100
Substrate Composition	**Bedrock (%)**	0	0	0	0	0	0
	Boulder (%)	0	2	0	0	0	0
	Rubble (%)	5	3	5	0	0	0
	Gravel (%)	10	10	15	10	0	5
	Sand (%)	10	55	25	30	0	5
	Silt (%)	10	0	0	10	0	0
	Clay (%)	0	30	50	15	0	0
	Muck (%)	45	0	0	20	80	40
	Detritus (%)	20	0	5	15	20	50
	Dreissenid Presence	Not Detected	Not Detected	Not Detected	Not Detected	Live	Shells Only

Table 7. Environmental data collected at each site in the Lake Erie watershed.

Site Details	Site Code	LER-EVC-01	LER-LYN-01	LER-SDK-01	LER-STO-01	LER-WDC-01
	Waterbody	Evans Creek	Lynn River	Sandusk Creek	Stoney Creek	Wardell Creek
	T. parvum Presence	Not Detected	Not Detected	Not Detected	Not Detected	Not Detected
Search Area Measurements	Length of Reach (m)	20	33	27	83	75
	Min Width of Reach (m)	10		30		22
	Max Width of Reach (m)	13	70	32	45	30
	Avg Width (m)	12				26
	Max Depth Searched (m)	1	0.85	1.05	0.7	1
	Avg Depth Searched (m)	0.80	0.85	1.00	0.58	0.90
	Water Clarity (m)	0.26		0.07	0.48	0.35
	Water Velocity (m/s)	0.033	0.000	0.011	0.004	0.006
	Stream Shading	Open	Partly Open	Open	Partly Open	Open
	Algal Growth	Present	Present	Present	Abundant	Abundant
YSI Measurements	Water Temperature (°C)	23.51	20.08	26.05	22.40	25.36
	Conductivity (us/cm)	361.8	680.0	484.1	393.5	295.8
	ODO (%)	66.4	47.6	109.5	93.5	110.5
	ODO (mg/L)	5.54	4.33	8.84	8.07	9.10
	pH	7.7	7.82	8.26	8.31	8.17
	Salinity (psu)	0.18	0.37	0.23	0.20	0.14
	TDS (mg/L)	243.319	487.958	308.717	269.245	191.295
	Turbidity (FNU)	11.08	3.52	81.38	15.14	12.70
Stream Morphology	Riffle (%)	0	0	0	0	0
	Pool (%)	0	100	0	100	0
	Run (%)	100	0	100	0	100
	Flat (%)	0	0	0	0	0
Substrate Composition	Bedrock (%)	0	0	0	10	0
	Boulder (%)	0	0	0	0	0
	Rubble (%)	0	0	0	10	0
	Gravel (%)	0	0	5	10	0
	Sand (%)	0	0	0	0	20
	Silt (%)	0	0	0	5	0
	Clay (%)	5	0	10	0	5
	Muck (%)	60	60	70	30	65
	Detritus (%)	35	40	15	35	10
	Dreissenid Presence	Live	Not Detected	Shells Only	Live	Shells Only

Table 8. Environmental data collected at each site in the Lake Ontario watershed.

		Site Code	LON-SPC-04	LON-SPC-05
Site Details		Waterbody	Spencer Creek	Spencer Creek
		T. parvum Presence	Not Detected	Not Detected
Search Area Measurements		Length of Reach (m)	101	46
		Min Width of Reach (m)	15.5	2.0
		Max Width of Reach (m)	17.5	6.0
		Avg Width (m)	16.5	4.0
		Max Depth Searched (m)	1.25	1.1
		Avg Depth Searched (m)	1.05	1.00
		Water Clarity (m)	0.290	0.222
		Water Velocity (m/s)	0.026	0.047
		Stream Shading	Partly Open	Open
		Algal Growth	Absent	Absent
YSI Measurements		Water Temperature (°C)	15.99	16.64
		Conductivity (us/cm)	809.0	833.0
		ODO (%)	85.6	91.3
		ODO (mg/L)	8.41	8.87
		pH	8.20	8.25
		Salinity (psu)	0.49	0.49
		TDS (mg/L)	635.315	644.299
		Turbidity (FNU)	17.4	15.0
Stream Morphology		Riffle (%)	0	0
		Pool (%)	0	0
		Run (%)	0	10
		Flat (%)	100	90
Substrate Composition		Bedrock (%)	0	0
		Boulder (%)	0	0
		Rubble (%)	0	0
		Gravel (%)	0	0
		Sand (%)	0	5
		Silt (%)	10	0
		Clay (%)	85	85
		Muck (%)	0	5
		Detritus (%)	5	5
		Dreissenid Presence	Not Detected	Not Detected

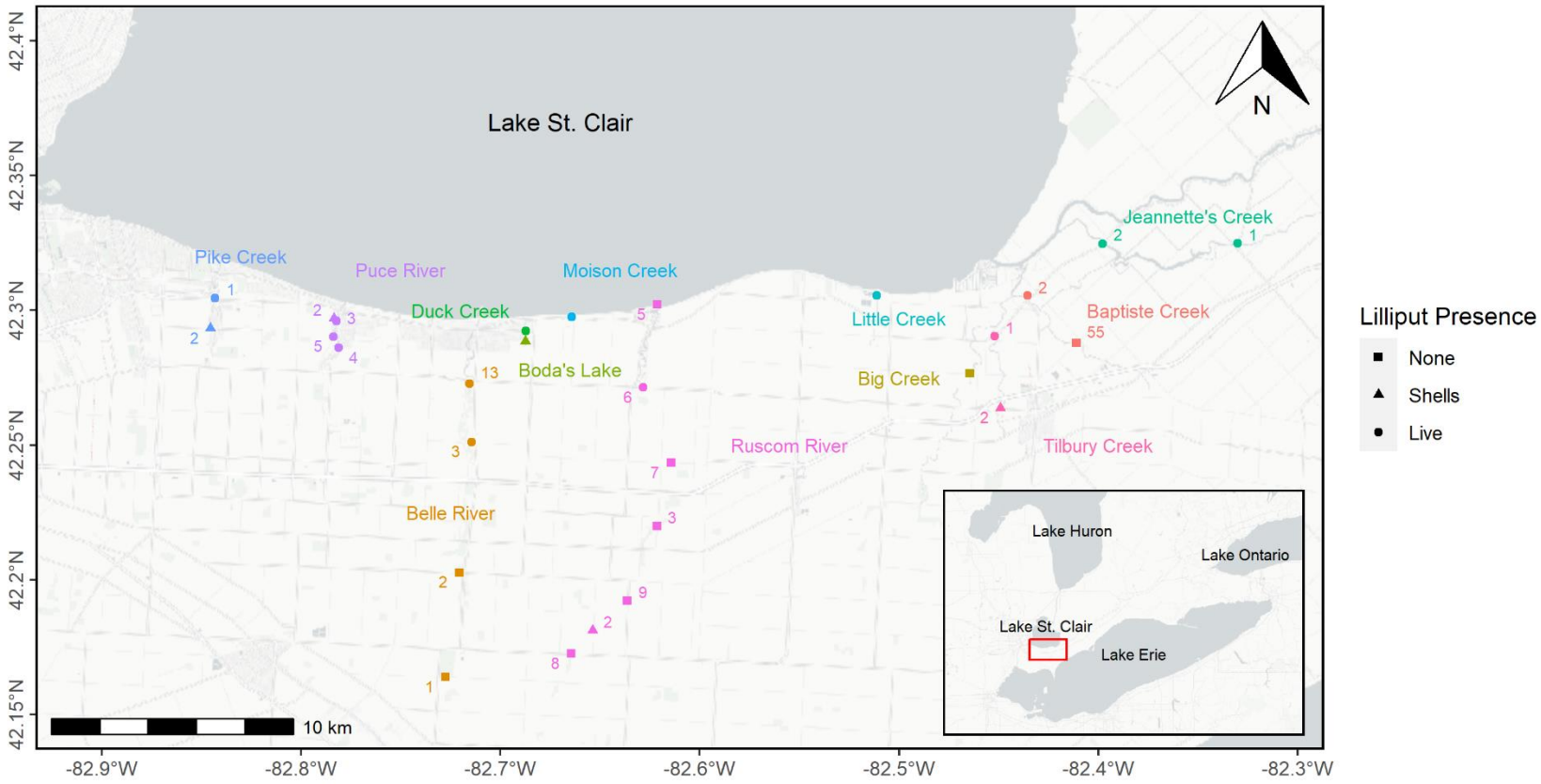

Figure 1. Sites sampled in the Lake St. Clair watershed in 2022. Sites are labelled with the site code suffix for sites in waterbodies containing more than one site; refer to Table 1 for the full site code. Map tiles by CartoDB, under CC BY 3.0. Data by OpenStreetMap, under ODbL.

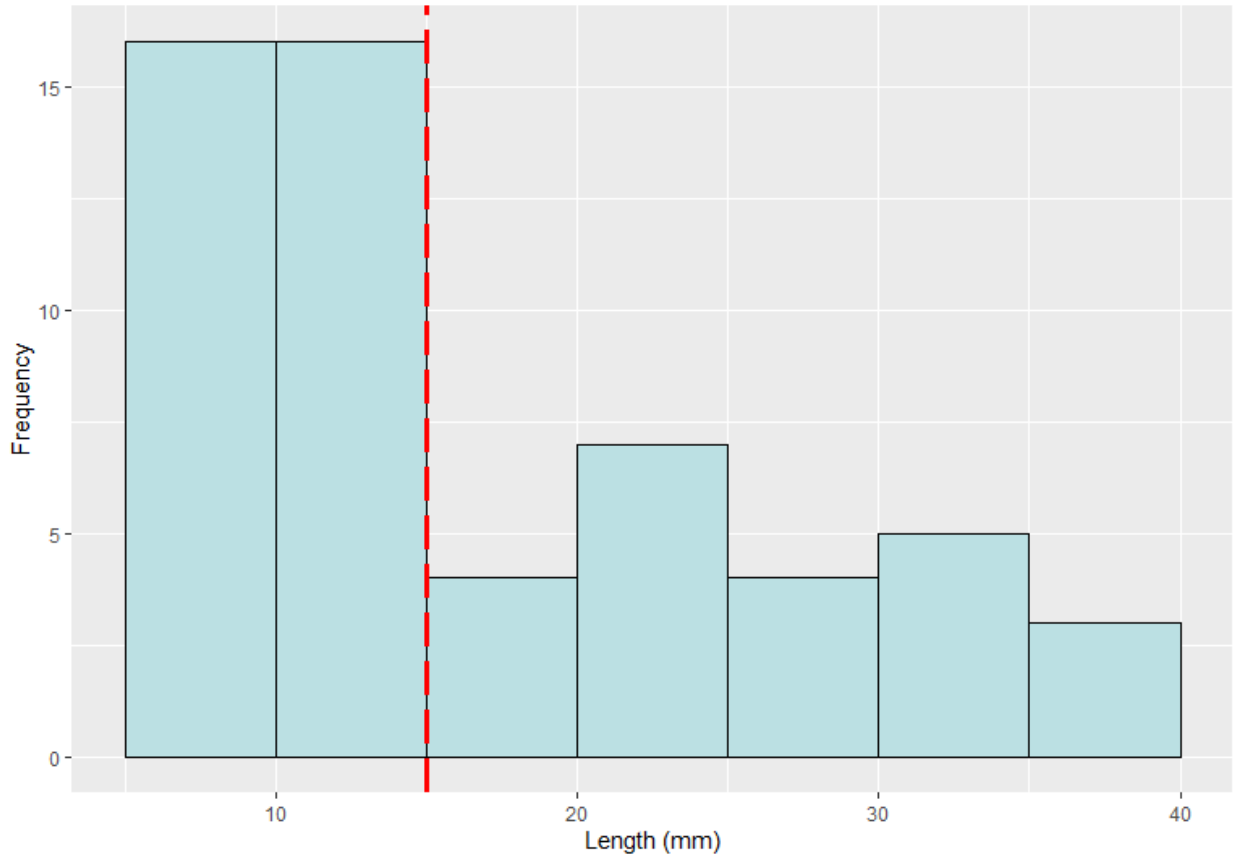

Figure 2. Length frequency of *Toxolasma parvum* (Lilliput, n = 55) found at 14 sites in the Lake St. Clair watershed. The dashed vertical line represents the division between *T. parvum* juveniles (<15.0 mm) and adults (≥15.0 mm).

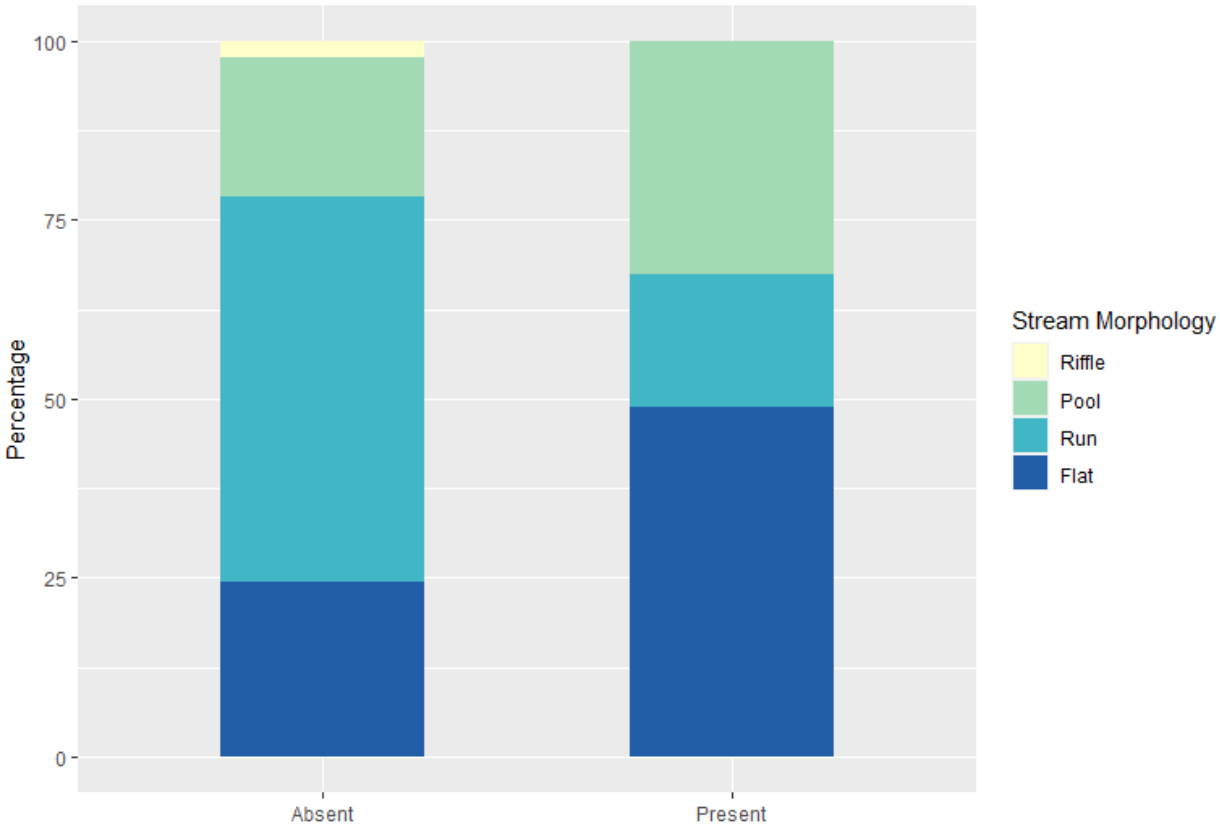

Figure 3. Comparison of mean percentage of riffle, pool, run, and flat stream morphology across sites where *Toxolasma parvum* (Lilliput) was present (live or shells) and absent.

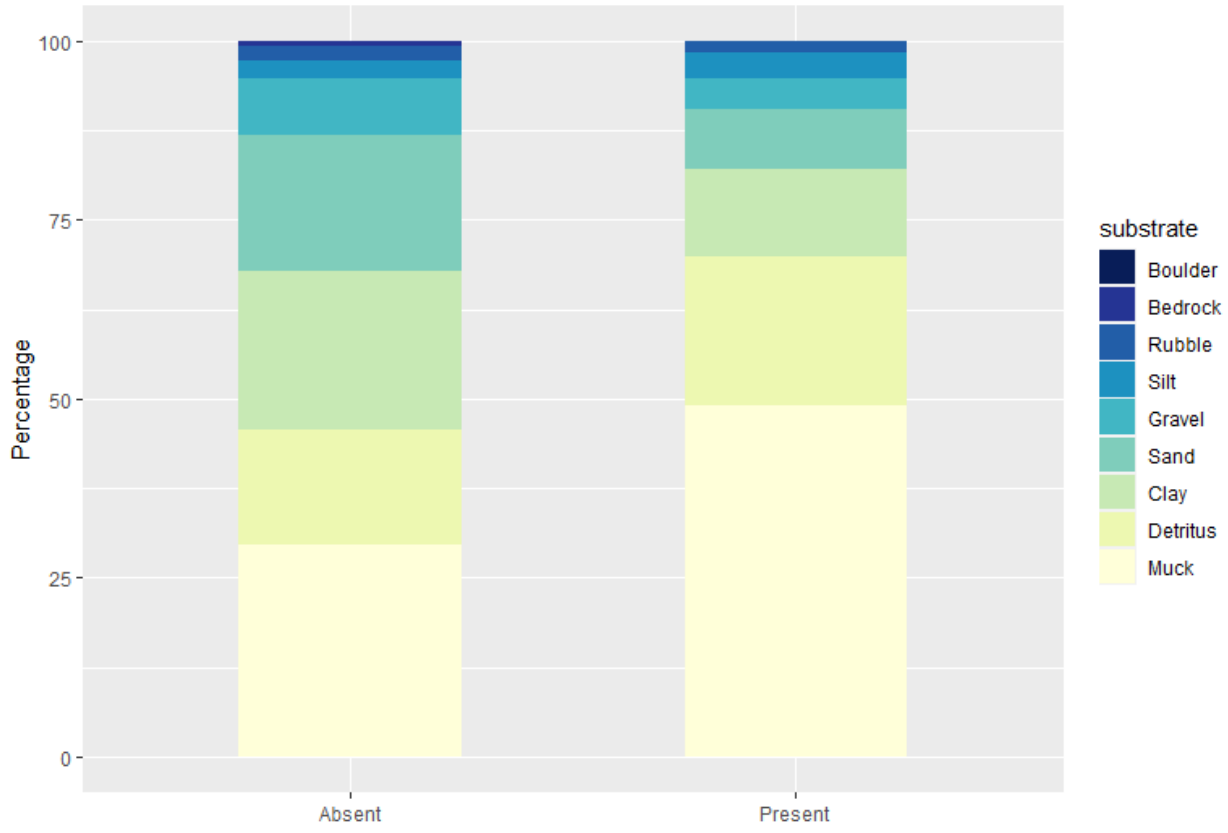

Figure 4. Comparison of mean percentage of substrate across sites where *Toxolasma parvum* (Lilliput) was present (live or shells) and absent.

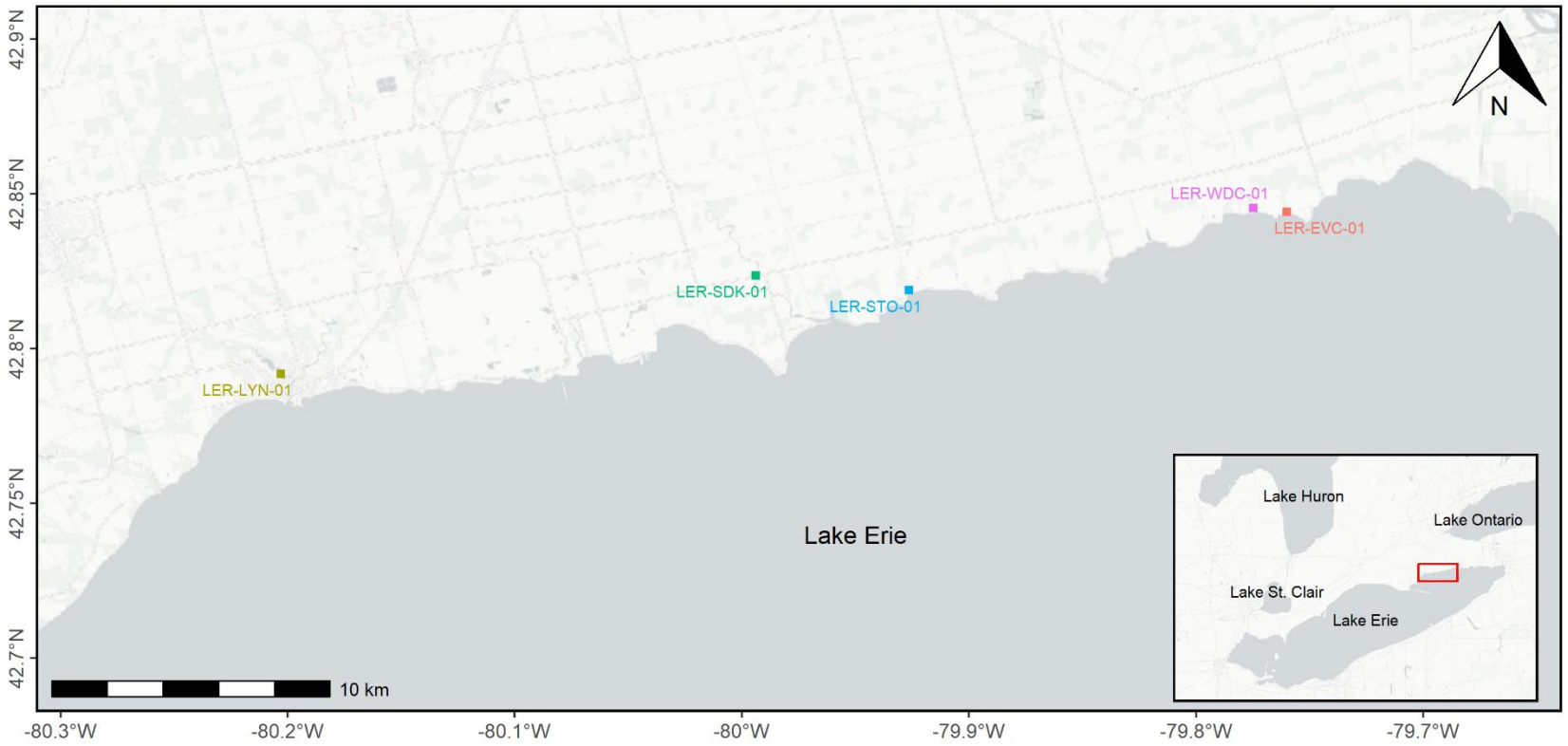

Figure 5. Sites sampled in the Lake Erie watershed in 2022. Map tiles by CartoDB, under CC BY 3.0. Data by OpenStreetMap, under ODbL.

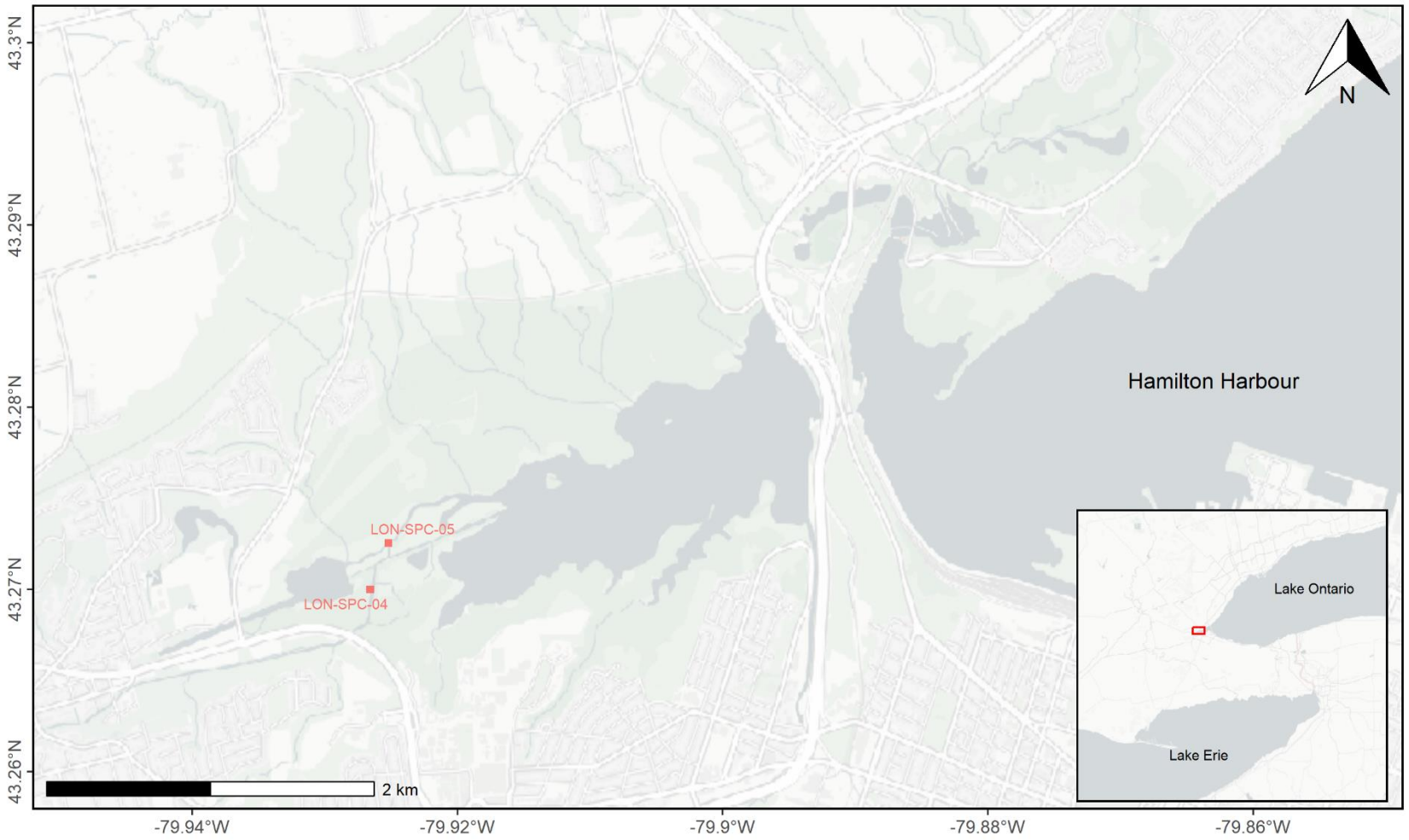

Figure 6. Sites sampled in the Lake Ontario watershed in 2022. Map tiles by CartoDB, under CC BY 3.0. Data by OpenStreetMap, under ODbL.