

# **Timed-search surveys of freshwater mussels in coastal wetland and riverine sites in lakes Ontario, Erie, and St. Clair in 2015**

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## ABSTRACT

Wright, K.A., McNichols-O'Rourke, K.A., and Morris, T. J. 2020. Timed-search surveys of freshwater mussels in coastal wetland and riverine sites in lakes Ontario, Erie, and St. Clair in 2015. Can. Manuscr. Rep. Fish. Aquat. Sci. 3192: v + 24 p.

In 2015, Fisheries and Oceans Canada (DFO) surveyed 41 coastal wetland and riverine sites in the Lake Ontario, Lake Erie, and Lake St. Clair drainages for freshwater mussels. Twenty-seven live species (744 individuals), including eight Species at Risk (SAR), were observed. Although all riverine sites had previously been sampled, a number of the coastal wetland sites (Four Mile Creek, Fifteen Mile Creek, Cootes Paradise Marsh, and Martindale Pond) had never been formally surveyed by DFO. Species richness at coastal wetland sites ranged from zero to five and *Pyganodon grandis* was the most abundant species. The first live occurrence of *Quadrula quadrula*, a SAR, was recorded in Fifteen Mile Creek. Cootes Paradise Marsh maintains a mussel community represented by at least five different species and the presence of *Toxolasma parvum* was confirmed. Riverine sites (Credit, Grand, Speed, and Sydenham rivers) were sampled for data on target species, and richness ranged from two to 18 species, including six SAR. No mussels were observed in Bronte Creek or Sixteen Mile Creek-Halton. Our findings allow for a better understanding of the ranges and population statuses of SAR in these areas.

## RÉSUMÉ

Wright, K.A., McNichols-O'Rourke, K.A., and Morris, T.J. 2020. Timed-search surveys of freshwater mussels in coastal wetland and riverine sites in lakes Ontario, Erie, and St. Clair in 2015. Can. Manuscr. Rep. Fish. Aquat. Sci. 3192: v + 24 p.

En 2015, Pêches et Océans Canada (MPO) a mené des relevés ciblant les moules d'eau douce dans 41 milieux humides côtiers et sites riverains situés dans les bassins hydrographiques des lacs Ontario, Érié et Sainte-Claire. Dans le cadre de ces relevés, on a observé 27 espèces vivantes (744 individus), y compris huit espèces en péril. Tous les sites riverains en question avaient déjà été échantillonnés, mais le MPO n'avait jamais mené de relevé officiel dans certains milieux humides côtiers, comme le ruisseau Four Mile, le ruisseau Fifteen Mile, le marais Cootes Paradise et l'étang Martindale. Dans les milieux humides côtiers étudiés, la richesse spécifique variait de zéro à cinq espèces, et le Grand Anodonte (*Pyganodon grandis*) était l'espèce la plus abondante. Le premier spécimen vivant de Mulette-feuille d'érable (*Quadrula quadrula*), une espèce en péril, a été observé dans le ruisseau Fifteen Mile. Le marais Cootes Paradise abrite une communauté de moules comptant au moins cinq espèces différentes, y compris le Toxolasme nain (*Toxolasma parvum*) dont on a confirmé la présence. On a échantillonné des sites riverains (rivières Credit, Grand, Speed et Sydenham) afin d'obtenir des données sur des espèces cibles. La richesse spécifique y variait de deux à 18 espèces, parmi lesquelles on comptait six espèces en péril. Aucune moule n'a été observée dans le ruisseau Bronte ni dans le ruisseau Sixteen Mile (région de Halton). Les résultats obtenus permettent de mieux comprendre l'aire de répartition d'espèces en péril et la situation de leurs populations dans les zones étudiées.

## INTRODUCTION

As 70% of North American freshwater mussel species are extinct or imperiled (U.S. Fish and Wildlife Service 2016), research and conservation efforts focusing on species' assessment and habitat continue to be important. Currently, 15 of 42 Ontario species are considered at risk and are listed as Endangered, Threatened, or Special Concern under the *Species at Risk Act* (SARA) (Table 1; Government of Canada 2020; Metcalfe-Smith et al. 2005). Ontario species, like almost all North American freshwater mussels, are threatened by habitat loss and invasive mussels, notably the Zebra Mussel (*Dreissena polymorpha*) and Quagga Mussel (*Dreissena rostriformis bugensis*) (COSEWIC 2006). Other threats include, but are not limited to, pollution (e.g., from urban and agricultural runoff), climate change, residential and commercial development, and other anthropogenic disturbances (COSEWIC 2006; 2013).

As conservation activities have focused heavily on riverine populations in southwestern Ontario, Reid et al. (2014) examined methods to inventory and monitor lesser studied wetland areas. Wetlands regulate chemical, biological, and ecological processes of a lake and thus are important for productivity, nutrient cycling, biodiversity, and fisheries (Sierszen et al. 2012). They also offer refuge for many mussel species (Zanatta et al. 2015). One such area is Cootes Paradise Marsh, a large coastal wetland complex of 320 Ha at the western end of Lake Ontario in Hamilton, Ontario. Shoreline searches and incidental observations have been recorded by the staff at the Royal Botanical Gardens (RBG) since the mid-1990s (Smith 2008). In-water surveys in Cootes Paradise Marsh were conducted by the Ontario Ministry of Natural Resources and Forestry (OMNRF) in 2013. Additional wetland sites examined by Reid et al. (2014) were located from St. Catharines to Kingston along the coast of Lake Ontario. Other areas within and beyond this range have yet to be explored or have not been formally surveyed.

During the 2015 field season, Fisheries and Oceans Canada (DFO) surveyed for freshwater mussels at coastal wetland and riverine sites within the Lake Ontario and Lake Erie drainages. The overall goal was to gather information on distributions and abundances of mussel Species at Risk (SAR), as well as provide a general description of the habitat at the sites. Specific purposes of surveying were to:

- (1) Determine or confirm the range of target mussel SAR that had previously been reported at one or more sites within the system: Cootes Paradise Marsh and Sixteen Mile Creek-Niagara\*;
- (2) Create mussel inventories of waterbodies or sites that had never been formally surveyed by DFO: Cootes Paradise Marsh, other coastal wetland areas (Four Mile Creek, Fifteen Mile Creek, and Martindale Pond), and lower portions of Bronte Creek and Sixteen Mile Creek-Halton\*;



- (3) Revisit sites to collect information about a specific species or to collect genetic samples: Grand, Speed, Sydenham, and Credit rivers, and Sixteen Mile Creek-Niagara.

## **METHODS**

### **COASTAL WETLAND SEARCH METHOD**

This method was used in coastal wetland areas that had never been previously sampled: Four Mile Creek, Fifteen Mile Creek, and Martindale Pond. Surveys were conducted in collaboration with the OMNRF or Central Michigan University (CMU) and consisted of two person-hours of sampling: one person-hour of tactile searching, using hands and/or boots to feel through the substrate for mussels, and one person-hour with either mussel scoops (122 cm (4 ft) long handle with a 7 mm mesh metal basket) or an Eagle Claw® Clam Rake (0.84 m long handle, with 0.26 x 0.15 m metal basket and ten 0.15 m long steel teeth) (Reid et al. 2014). Sampling was limited to within 50 m of the starting point and methods did not overlap within the sampling area. At one site in Fifteen Mile Creek, LON-FML-02, the large amount of vegetation made the mussel scoops ineffective for sampling; only the first hour of sampling (tactile searching) was completed, despite the intent to complete both components of the coastal wetland search method. During the surveys, all live animals were removed from the substrate and placed in a mesh diver's bag. At the end of the sampling period, mussels from all collectors were combined, identified to species, sexed (if possible), and returned to the area from which they were collected. For sites where no live mussels of a given species were found, shells and valves were noted; for sites where live mussels and shells and/or valves of a species were found, only live were noted.

### **TIMED-SEARCH METHOD**

The standard timed-search method (Metcalf-Smith et al. 2000) was completed at both coastal wetland and riverine sites where previous surveys, either formal or informal (observational records and incidental catches) had occurred: Cootes Paradise Marsh, Sixteen Mile Creek-Niagara, and riverine sites. A combination of tactile and visual techniques was used due to differences in water clarity. Clear water allowed the use of viewing boxes, while turbid water required tactile techniques. Additionally, mussel scoops were used to sample deeper areas and target juveniles. Live mussels were collected and processed in the same manner as described above in the coastal wetland search method. Surveys varied in effort depending on the specific goals at each site.

### **ABIOTIC FACTORS**

Physical and environmental variables were also recorded at each site: substrate composition was estimated visually; water clarity was measured using a turbidity tube;

length and width of reach were measured using a range finder (Nikon Laser 1200S) and mean depth was measured with a metre stick. Definitions of substrate sizes were the same as Morris et al. (2012a) which were altered from Wentworth (1922): boulder (>250 mm in diameter), rubble (60-250 mm), gravel (20-50 mm), sand (<2 mm), and “other” material (clay, mud, muck, silt, and detritus).

## RESULTS

### OVERALL FRESHWATER MUSSEL COMMUNITY

Between May and October 2015, 41 sites were visited across 12 waterbodies (Table 2; Figure 1). The coastal wetland survey technique was used at 18 sites throughout Four Mile Creek, Fifteen Mile Creek, and Martindale Pond (Table 3). Standard timed-searches occurred at 23 sites and ranged from two to 12.7 person-hours of searching (mean: 4.6 person-hours). Sites surveyed using this method included: Cootes Paradise Marsh (including two sites from Spencer Creek), Grand, Speed, Credit, and Sydenham rivers; Bronte Creek, Sixteen Mile Creek-Halton, and Sixteen Mile Creek-Niagara (Tables 4 and 5).

Across all sites, a total of 744 live mussels were found. These represented 27 species including eight SAR. Three additional SAR were observed only as shells (*Ligumia nasuta* in Cootes Paradise Marsh site LON-CTP-06, *Obliquaria reflexa*, and *Villosa iris* in the Grand River site GR-06). Abundance and species richness of live mussels varied from zero at 16 sites to 197 individuals of 18 species in the Sydenham River (SR-17).

### SITES SURVEYED USING THE COASTAL WETLAND SEARCH METHOD

In the 18 coastal wetland sites (Four Mile Creek, four sites; Fifteen Mile Creek, six sites; and Martindale Pond, eight sites; Figure 2) surveyed using the coastal wetland method, 54 live individuals representing four species, including one SAR, were found (Table 3). LON-FML-05 in Fifteen Mile Creek had the highest abundance (42 individuals) as well as the highest live species richness (three species). *Pyganodon grandis* was the most abundant (40 live individuals) and also had the highest occurrence, being found live at seven of 18 sites and as valves/shells at five other sites. One species (*Lampsilis siliquoidea*) was found as only a valve/shell at two sites, bringing the total species richness to five (Table 3). *Quadrula quadrula*, the single SAR observed, was found live for the first time in Fifteen Mile Creek with 12 individuals observed at LON-FML-05.

### SITES SURVEYED USING THE TIMED-SEARCH METHOD

## Coastal wetland sites

Thirteen coastal wetland sites were surveyed using the timed-search method: three in Sixteen Mile Creek-Niagara and 10 in Cootes Paradise Marsh, including two in Spencer Creek.

In Sixteen Mile Creek-Niagara (Figure 2), 23 live individuals representing three species, including one SAR, were found (Table 4). SMC-NIAGARA-05 had the highest abundance (16 individuals) as well as the highest live species richness (three species). *Quadrula quadrula*, the only SAR observed, was the most abundant species (10 live individuals at one site with two shells at another). *Pyganodon grandis* had the highest occurrence, being found live at all three sites. One species (*Leptodea fragilis*) was found only as shells at one site, bringing the total species richness to four.

In the 10 sites surveyed across Cootes Paradise Marsh and Spencer Creek (Figure 3), a total of 147 live individuals, representing six species including two SAR, were found (Table 4). *Utterbackia imbecillis* was the most abundant (95 live individuals) and also had the highest frequency of occurrence (9 of 10 sites). *Toxolasma parvum*, a SAR, was the second most abundant species with 27 live individuals found from seven sites and one shell at an additional site (LON-CTP-01). Both *U. imbecillis* and *T. parvum* were represented by multiple size classes (Figures 4-5) and had normal length distributions ( $W = 0.961$ ,  $p = 0.81$  and  $W = 0.874$ ,  $p = 0.20$ , respectively). The second SAR, *Quadrula quadrula* was found live (2 individuals) at a single site, LON-CTP-06. This site had the highest species richness in the marsh and also included the only record of *L. nasuta* (a single shell) observed during this sampling event.

## Riverine sites

Across the 10 riverine sites, the most abundant species at each site varied among common species (Table 5). Sydenham River site SR-17 had the highest abundance (197 live individuals) and live species richness (18 species), followed by Grand River site GR-06 (156 live individuals; 12 species). No mussels were observed in the lower portions of Bronte Creek or Six Mile Creek-Halton (Table 5; Figure 6).

## **ABIOTIC FACTORS**

The physical data collected at each sampled site is summarized in Table 6. It was meant to provide a general description of the overall site and not address issues relating to species microhabitat preference. Not all sites were included in the means presented below as some data were not collected at each site during sampling. At coastal wetland sites surveyed using the coastal wetland technique (Four Mile Creek, Fifteen Mile Creek, and Martindale Pond), the substrate was fine-textured with an average of 76.81% “other” material (clay, muck, mud, silt, and detritus). This was reflected in the water clarity as mean visibility was 0.19 m. Mean site length was 41.63 m, mean width was 13 m, and mean depth was 0.81 m. Coastal wetland sites surveyed using the timed-search method (Cootes Paradise Marsh and Sixteen Mile Creek) had very fine-textured substrate with 91.46% “other” material and mean visibility of 0.27 m.

Mean site length was 131.64 m, mean width was 19.27 m, and mean depth was 0.66 m. Riverine sites had substrate that was less fine-textured with an average of 30% “other” material and mean visibility of 0.50 m. Mean site length was 202.22 m, mean width was 31.25 m, and mean depth was 0.61 m.

## DISCUSSION

### COASTAL WETLAND SITES

#### Coastal wetland search method

Four Mile Creek, Fifteen Mile Creek, and Martindale Pond had not been previously surveyed; however, populations of SAR have been found in other coastal wetlands along Lake Ontario. For example, Reid et al. (2014) found small populations of *L. nasuta* at five sites in coastal wetland areas when this species was believed to be extirpated from Lake Ontario (COSEWIC 2007). Additionally, a population of *Q. quadrula* in Jordan Harbour (located just east of Sixteen Mile Creek-Niagara) was found by OMNRF in 2012 (Lower Great Lakes Unionid Database 2020), which was the first reported occurrence of this species in the Lake Ontario drainage. This species still occurs in parts of its historic distribution in lakes Erie and St. Clair as well as the Sydenham, Thames, Grand, Welland, and Niagara rivers. Since 2013, it has been observed in a number of additional waterbodies including tributaries of Lake Huron as well as additional tributaries in lakes St. Clair, Erie, and Ontario (Lower Great Lakes Unionid Database 2017; Morris et al. 2012a; 2012b).

Compared to riverine sites, species richness was low across coastal wetland sites; the highest live richness was three species and this occurred at two sites. *Quadrula quadrula* was the only SAR found in the coastal wetland sites surveyed during this study. *Pyganodon grandis* was the most abundant species overall, with the highest number occurring in Fifteen Mile Creek. Sites in Martindale Pond, which contained only two live *P. grandis* and one *L. fragilis* valve, differed from Fifteen Mile Creek in certain abiotic characteristics, especially degree of siltation (e.g., water clarity was higher in Martindale Pond).

#### Timed-search method

Timed-searches were completed in coastal wetland areas of Cootes Paradise Marsh and Sixteen Mile Creek-Niagara during targeted surveys. Sixteen Mile Creek-Niagara was surveyed in 2013 by the OMNRF and three species were found alive: *P. grandis*, *Q. quadrula*, and *U. imbecillis* (Lower Great Lakes Unionid Database 2020). Live individuals of these three species were also found during the present study, confirming their presence in this waterbody. A single *Elliptio complanata* valve was also found during the 2013 study; however, it was not observed during the current survey alive or as valves/shells.

Species found in Cootes Paradise Marsh in 2015 have also been observed in other waterbodies (Sunfish Pond, Grindstone Creek, and Carroll's Bay) on the RBG property via RBG staff shell surveys and formal DFO surveys in 2011 (Minke-Martin et al. 2014). The presence of stable mussel populations in Cootes Paradise Marsh is promising as this area is part of Project Paradise, a restoration initiative of wetland complexes protected within RBG (RBG 2011). Mussels play many roles in aquatic ecosystems including removing materials from the water column by suspension feeding, mixing sediment pore water and releasing nutrients by burrowing, providing food for other animals, providing habitat in their empty shells, and recycling calcium carbonate back to the ecosystem when their shells erode (Grabarkiewicz and Davis 2008). Additionally, they are considered biological indicators of ecosystem health (Grabarkiewicz and Davis 2008).

The mussel populations that once resided in the open waters of the Great Lakes have been eradicated by Dreissenid mussels. One example of Dreissenid caused decimation is the Detroit River where surveys have shown that native mussel populations have been either completely extirpated or decreased to levels where they are no longer able to viably reproduce (Schloesser et al. 2006), although recent work by Allred et al. (2019) (*in* Morris et al. 2020) has shown that some unionids remain. Coastal wetland areas are important habitats for mussels in the Great Lakes. They appear to act as refugia and represent some of the only remaining mussel habitats in these waters. Refuge sites in lakes Erie and St. Clair are very shallow and highly connected to the lake, which, combined with local factors, discourages Dreissenid settlement and survival (Zanatta et al. 2002). It is important to continue monitoring refuge sites and Dreissenid populations.

Based on the current survey, Cootes Paradise Marsh represents the largest known populations of *T. parvum* and *U. imbecillis* in Canada. Both species had high live occurrences and appear to be reproducing based on the observation of multiple size classes and normal length distributions. *Utterbackia imbecillis* is a common species found throughout most of southwestern Ontario (Canadian Freshwater Mussel Guide n.d.). *Toxolasma parvum*, on the other hand, is listed as Endangered under SARA (Government of Canada 2020). Its distribution is limited in Canada due to invasive species, pollution from urban development, and sedimentation (COSEWIC 2013). According to COSEWIC (2013), *T. parvum* have previously been observed in Sunfish Pond in Hamilton Harbour; our observation of this species in Cootes Paradise Marsh thus confirms its presence in this waterbody.

It is unclear whether the two other observed SAR (*Q. quadrula* and *L. nasuta*) represent established populations. Although it is impossible to comment on the status of the *Q. quadrula* population in Cootes Paradise Marsh based on two live individuals, these records increase the number of potential subpopulations of this species. These records, paired with the recent downlisting of *Q. quadrula* in the Great Lakes-Upper St. Lawrence drainage from Threatened to Special Concern (Government of Canada 2020), are encouraging for the *Q. quadrula* species as a whole. This population also represents the most distant record of *Q. quadrula* from its introduction source of Lake Ontario. Conservation genetics techniques suggest that this species entered the Great Lakes-Upper St. Lawrence during the first iteration of the Welland Canal by way of a

connection between the Lower Grand, Welland River, and Lake Ontario (Hoffman 2016).

*Ligumia nasuta* was originally listed as Endangered under SARA, however it was recently downlisted to Special Concern (Government of Canada 2020). COSEWIC (2007) stated that *L. nasuta* was likely extirpated from Canadian waters of Lake Ontario and only remained in the St. Clair River delta. Since then, Reid et al. (2014) found small remnant populations of *L. nasuta* in five wetlands along Lake Ontario. The only evidence of *L. nasuta* during the current survey was a single fresh shell at LON-CTP-06. This species was first collected in this area as a fresh shell in 2007 at Hopkin's Bay (Paul Smith, Royal Botanical Gardens, 680 Plains Rd W, Burlington, ON, L7T 4H4, pers. comm.) and later as a second shell in lower Spencer Creek (Tys Theysmeyer, Royal Botanical Gardens, 680 Plains Rd W, Burlington, ON, L7T 4H4, pers. comm.). Additional surveys of waterbodies on the RBG property are recommended to determine if a subpopulation of *L. nasuta* exists in this area.

Of the Cootes Paradise Marsh sites, LON-CTP-06 contained the most diverse unionid fauna with twice as many species as any other site, including the presence of *T. parvum* and the only two records of *Q. quadrula*. The substrate at LON-CTP-06 consisted of 15% gravel, 15% sand, and 70% "other" material (clay, muck, mud, silt, and detritus), which was notably different than substrate at the other sites that consisted of less than 3% gravel or sand and over 90% "other" material. As *Q. quadrula* is most commonly found in gravel, sand, or clay/mud (COSEWIC 2006), the high presence of gravel and sand at LON-CTP-06 could be the reason that this was the only site with observations of *Q. quadrula*. Live observations of *L. fragilis*, which prefers muddy gravel (Krebs 2015), only occurred at LON-CTP-06 and its neighbouring site LON-CTP-07. The single shell of *L. nasuta*, which was the only evidence of this species in Cootes Paradise Marsh, was also observed at LON-CTP-06. *Pyganodon grandis* was found in Spencer Creek, LON-CTP-06, and other north shore sites in Cootes Paradise, as well as at a south shore site; this could also indicate habitat or movement of its host fish species. The remaining two species found at LON-CTP-06, *T. parvum* and *U. imbecillis*, were also found at most or all of the other sites, respectively. Both of these species are found in soft substrates of mud, sand, or silt (COSEWIC 2013; Parmalee and Polhemus 2004), which occurred at all sites.

## RIVERINE SITES

Previous surveys have been conducted in the Grand (McNichols-O'Rourke et al. 2012), Speed, Credit, and Sydenham rivers (Lower Great Lakes Unionid Database 2020). These sites were resampled in 2015 for various projects with specific objectives. The Grand, Speed, and Credit rivers were each revisited to collect genetic samples from specific mussel species. The site in the Sydenham River was resampled to collect gravid female mussels for propagation experiments. This site has been well sampled using both quantitative and qualitative sampling techniques. All of the species that were collected in the riverine sites had been previously observed; no new species were detected during these targeted sampling events.

Surveys were conducted by DFO and Environment and Climate Change Canada (formerly Environment Canada) in the upper portions of Bronte Creek and Sixteen Mile

Creek-Halton in 1996; an additional survey was conducted in Bronte Creek by Berg in 1975 (Lower Great Lakes Unionid Database 2020). These historical surveys in Bronte Creek detected five live individuals of *Anodontoidea ferussacianus* as well as shells/valves of *P. grandis*, *L. siliquoidea*, and *Lasmigona compressa*. Historical surveys in Sixteen Mile Creek-Halton detected live records of *Actinonaias ligamentina*, *Alasmidonta marginata*, *L. siliquoidea*, and *P. grandis*. *Anodontoidea ferussacianus* and *L. compressa* were also found as shells/valves. None of these were SAR. The surveys conducted by DFO in 2015 targeted the lower portions of Bronte Creek and Sixteen Mile Creek-Halton; no live individuals or shells/valves were observed. It is important to note that in 2015 only three sites were surveyed on the lower portion of Bronte Creek and two on Sixteen Mile Creek-Halton; therefore, further surveys should be completed in order to determine where mussels begin to appear in these systems.

## CONCLUSION

In 2015, mussel surveys were conducted for three purposes: to determine or confirm the range of certain SAR, create mussel inventories of waterbodies/sites that had never been formally surveyed by DFO, and to revisit sites to collect specific information or genetic samples of target species. Forty-one sites in 12 waterbodies were visited and a total of 744 individuals representing 27 live mussel species, including eight SAR, were observed. Three additional SAR were found as shells or valves. The new records generated for *Q. quadrula* and *L. nasuta* will allow for a better understanding of their ranges and will assist with the protection and recovery of these at-risk species.

Each of the coastal wetland sites (Four Mile Creek, Fifteen Mile Creek, Sixteen Mile Creek-Niagara, and Martindale Pond) that had not been previously surveyed (or formally surveyed) had a maximum of three species observed. *Pyganodon grandis* was the most abundant species in sites surveyed using the coastal wetland technique. The only SAR observed, *Q. quadrula*, was the most abundant species in sites surveyed using the timed-search method and a new live record was obtained at the mouth of Fifteen Mile Creek.

It appears that Cootes Paradise Marsh still maintains a well-established mussel community. Mussels were widespread throughout the area (individuals were found at all sites sampled); however, abundances were relatively low. The mussel community is dominated by *U. imbecillis* which represents 65% of live individuals encountered. A large and seemingly reproducing population of *T. parvum* occurs in the area. Additionally, new records were generated for live *Q. quadrula*, a shell of *L. nasuta* was observed, and the presence of *T. parvum* was confirmed. Coastal wetland areas, such as Cootes Paradise Marsh, are important habitats for mussels in the Great Lakes as they can act as refugia from Dreissenid mussels.

The data collected during the 2015 surveys has provided information on the freshwater mussel communities in a number of different waterbodies as well as additional information on three mussel SAR found in Ontario. These sampling events have detected/confirmed new subpopulations of certain SAR and given an opportunity to determine if these populations are showing recruitment as well as identified knowledge gaps that are required to determine the status of these populations.

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Table 1. Mussel species in Ontario that have been listed under the *Species at Risk Act* (SARA) as of February 2020 (Government of Canada 2020).

Scientific Name	Common Name	SARA status
<i>Epioblasma rangiana</i>	Northern Riffleshell	Endangered
<i>Epioblasma triquetra</i>	Snuffbox	Endangered
<i>Lampsilis fasciola</i>	Wavyrayed Lampmussel	Special Concern
<i>Ligumia nasuta</i>	Eastern Pondmussel	Special Concern
<i>Obliquaria reflexa</i>	Threehorn Wartyback	Threatened
<i>Obovaria olivaria</i>	Hickorynut	Endangered
<i>Obovaria subrotunda</i>	Round Hickorynut	Endangered
<i>Pleurobema sintoxia</i>	Round Pigtoe	Endangered
<i>Ptychobranhus fasciolaris</i>	Kidneyshell	Endangered
<i>Quadrula quadrula</i>	Mapleleaf	Special Concern (ON) Threatened (MB)
<i>Simpsonaias ambigua</i>	Salamander Mussel	Endangered
<i>Toxolasma parvum</i>	Lilliput	Endangered
<i>Truncilla donaciformis</i>	Fawnsfoot	Endangered
<i>Villosa fabalis</i>	Rayed Bean	Endangered
<i>Villosa iris</i>	Rainbow	Special Concern

Table 2. Information on sites sampled or resampled in 2015. Icon numbers correspond to site codes on Figures 1-3 and 6.

	Site Code	Drainage	Waterbody	Latitude	Longitude	Date	Icon
<b>Cootes Paradise Marsh</b>	LON-CTP-01	Lake Ontario	Cootes Paradise	43.27438	-79.89631	20151014	1
	LON-CTP-02	Lake Ontario	Cootes Paradise	43.27592	-79.89613	20151014	2
	LON-CTP-03	Lake Ontario	Cootes Paradise	43.27426	-79.8983	20151014	3
	LON-CTP-04	Lake Ontario	Cootes Paradise	43.27451	-79.89798	20151014	4
	LON-CTP-05	Lake Ontario	Cootes Paradise	43.27344	-79.90019	20151014	5
	LON-CTP-06	Lake Ontario	Cootes Paradise	43.27737	-79.90678	20151016	6
	LON-CTP-07	Lake Ontario	Cootes Paradise	43.27921	-79.90472	20151016	7
	LON-CTP-08	Lake Ontario	Cootes Paradise	43.28096	-79.9014	20151016	8
	LON-SPC-01	Lake Ontario	Spencer Creek	43.27513	-79.91797	20151015	9
	LON-SPC-02	Lake Ontario	Spencer Creek	43.27708	-79.91187	20151015	10
<b>Coastal wetlands</b>	LON-FMC-01	Lake Ontario	Four Mile Creek	43.25607	-79.12043	20150616	11
	LON-FMC-02	Lake Ontario	Four Mile Creek	43.25588	-79.12067	20150616	12
	LON-FMC-03	Lake Ontario	Four Mile Creek	43.25592	-79.11969	20150616	13
	LON-FMC-04	Lake Ontario	Four Mile Creek	43.25529	-79.11945	20150616	14
	LON-FML-01	Lake Ontario	Fifteen Mile Creek	43.17906	-79.32027	20150617	15
	LON-FML-02	Lake Ontario	Fifteen Mile Creek	43.17911	-79.32082	20150617	16
	LON-FML-03	Lake Ontario	Fifteen Mile Creek	43.16822	-79.3168	20150617	17
	LON-FML-04	Lake Ontario	Fifteen Mile Creek	43.16502	-79.31492	20150617	18
	LON-FML-05	Lake Ontario	Fifteen Mile Creek	43.18155	-79.32122	20150617	19
	LON-FML-06	Lake Ontario	Fifteen Mile Creek	43.18146	-79.32057	20150617	20
	LON-MDP-01	Lake Ontario	Martindale Pond	43.19602	-79.27113	20150618	21
	LON-MDP-02	Lake Ontario	Martindale Pond	43.1889	-79.27415	20150618	22
	LON-MDP-03	Lake Ontario	Martindale Pond	43.18698	-79.2724	20150618	23
	LON-MDP-04	Lake Ontario	Martindale Pond	43.18654	-79.27435	20150618	24
	LON-MDP-05	Lake Ontario	Martindale Pond	43.18065	-79.27685	20150618	25
	LON-MDP-06	Lake Ontario	Martindale Pond	43.17785	-79.27281	20150618	26
	LON-MDP-07	Lake Ontario	Martindale Pond	43.19072	-79.27276	20150618	27
	LON-MDP-08	Lake Ontario	Martindale Pond	43.20047	-79.26721	20150625	28
	LON-SMC- NIAGARA-05	Lake Ontario	Sixteen Mile Creek- NIAGARA	43.157413	-79.33556	20150615	29
	LON-SMC- NIAGARA-21	Lake Ontario	Sixteen Mile Creek- NIAGARA	43.18067	-79.32691	20150619	30
	LON-SMC- NIAGARA-22	Lake Ontario	Sixteen Mile Creek- NIAGARA	43.172802	-79.32886	20150615	31
<b>Riverine sites</b>	GR-06	Lake Erie	Grand River	42.98833333	-79.870833	20150716	32
	LER-GRR-01	Lake Erie	Grand River	43.10969	-80.24605	20150805	33
	GRR-SPD-01	Grand River	Speed River	43.38785	-80.36719	20150805	34
	LON-BTE-13	Lake Ontario	Bronte Creek	43.39333	-79.7154	20150604	35
	LON-BTE-14	Lake Ontario	Bronte Creek	43.39661	-79.72557	20150604	36
	LON-BTE-15	Lake Ontario	Bronte Creek	43.40917	-79.74204	20150604	37
	LON-SMC- HALTON-12	Lake Ontario	Sixteen Mile Creek- HALTON	43.45025	-79.68471	20150605	38
	LON-SMC- HALTON-13	Lake Ontario	Sixteen Mile Creek- HALTON	43.45199	-79.69339	20150604	39
	LON-CRR-17	Lake Ontario	Credit River	43.78488	-80.13966	20150610; 20150709	40
	SR-17	Lake St. Clair	Sydenham River	42.67916667	-82.016667	20150903	41

Table 3. Number of individuals observed in coastal wetland sites surveyed using the coastal wetland method (Reid et al. 2014) during the 2015 field season. Species at Risk are highlighted. S (#) = species observed as whole shells (number of shells). V (#) = species observed as valves (number of valves).

Scientific Name	Common Name	Four Mile Creek				Fifteen Mile Creek						Martindale Pond							
		LON-FMC-01'	LON-FMC-02'	LON-FMC-03	LON-FMC-04	LON-FML-01	LON-FML-02	LON-FML-03	LON-FML-04	LON-FML-05'	LON-FML-06	LON-MDP-01'	LON-MDP-02'	LON-MDP-03'	LON-MDP-04'	LON-MDP-05'	LON-MDP-06'	LON-MDP-07'	LON-MDP-08'
<i>Lampsilis siliquoidea</i>	Fatmucket	-	V (3)	-	-	-	-	-	S (1)	-	-	-	-	-	-	-	-	-	-
<i>Leptodea fragilis</i>	Fragile Papershell	-	-	-	-	S (1)	S (2)	-	-	-	1	V (1)	-	-	-	-	-	-	-
<i>Pyganodon grandis</i>	Giant Floater	S (5)	S (1)	S (4)	S (2)	1	S (2), V (1)	1	1	29	6	1	-	-	-	-	-	-	1
<i>Quadrula quadrula</i>	Mapleleaf	-	-	-	-	-	-	-	-	12	-	-	-	-	-	-	-	-	-
<i>Utterbackia imbecillis</i>	Paper Pondshell	-	-	-	-	-	-	-	V (2)	1	-	-	-	-	-	-	-	-	-
Total No. of live individuals		0	0	0	0	1	0	1	1	42	7	1	0	0	0	0	0	0	1
Species richness (live)		0	0	0	0	1	0	1	1	3	2	1	0	0	0	0	0	0	1
Species richness (total)		1	2	1	1	2	2	1	3	3	2	2	0	0	0	0	0	0	1
Search effort (person-hours)		2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2

<sup>a</sup> represents presence of Zebra Mussels

Table 4. Number of individuals observed in coastal wetland areas surveyed using the timed-search method (Metcalf-Smith et al. 2000) during the 2015 field season. Species at Risk are highlighted. S (#) = species observed as whole shells (number of shells). V (#) = species observed as valves (number of valves).

Scientific Name	Common Name	Cootes Paradise Marsh								Spencer Creek		Sixteen Mile Creek-NIAGARA		
		LON-CTP-01	LON-CTP-02	LON-CTP-03'	LON-CTP-04	LON-CTP-05'	LON-CTP-06	LON-CTP-07	LON-CTP-08'	LON-SPC-01	LON-SPC-02'	LON-SMC-NIAGARA-05	LON-SMC-NIAGARA-21	LON-SMC-NIAGARA-22
<i>Lampsilis siliquoidea</i>	Fatmucket	-	-	-	-	-	-	-	-	1	-	-	-	-
<i>Leptodea fragilis</i>	Fragile Papershell	-	S (2), V (4)	S (1)	-	-	1	1	-	-	-	-	S (2)	-
<i>Ligumia nasuta</i>	Eastern Pondmussel	-	-	-	-	-	S (1)	-	-	-	-	-	-	-
<i>Pyganodon grandis</i>	Giant Floater	S (1)	-	-	-	1	3	1	S (1)	9	6	1	6	1
<i>Quadrula quadrula</i>	Mapleleaf	-	-	-	-	-	2	-	-	-	-	10	-	S (2)
<i>Toxolasma parvum</i>	Lilliput	S (1)	7	2	7	3	2	-	5	1	-	-	-	-
<i>Utterbackia imbecillis</i>	Paper Pondshell	6	17	1	20	4	8	11	12	S (1)	16	5	-	-
Total No. of live individuals		6	24	3	27	8	16	13	17	11	22	16	6	1
Species richness (live)		1	2	2	2	3	5	3	2	3	2	3	1	1
Species richness (total)		3	3	3	2	3	6	3	3	4	2	3	2	2
Search effort (person-hours)		4.5	4.5	5	5	4	4.55	4.55	4.55	4.5	4.5	7.5	4.5	3

' represents presence of Zebra Mussels

Table 5. Number of individuals observed in riverine sites surveyed using the timed-search method (Metcalf-Smith et al. 2000) during the 2015 field season. Species at risk are highlighted. S (#) = species observed as whole shells (number of shells). V (#) = species observed as valves (number of valves).

Scientific Name	Common Name	Grand River		Speed River	Credit River	Sydenham River	Bronte Creek			Sixteen Mile Creek	
		GR-06	LER-GRR-01	GRR-SPD-01	LON-CRR-17	SR-17	LON-BTE-13'	LON-BTE-14	LON-BTE-15	LON-SMC-HALTON-12'	LON-SMC-HALTON-13
<i>Actinonaias ligamentina</i>	Mucket	44	25	-	-	28	-	-	-	-	-
<i>Alasmodonta marginata</i>	Elktoe	1	-	1	-	3	-	-	-	-	-
<i>Ambelma plicata</i>	Threeridge	-	3	-	-	14	-	-	-	-	-
<i>Cyclonaias pustulosa</i>	Pimpleback	11	-	-	-	2	-	-	-	-	-
<i>Cyclonaias tuberculata</i>	Purple Wartyback	-	-	-	-	3	-	-	-	-	-
<i>Eurynia dilatata</i>	Spike	-	-	-	-	7	-	-	-	-	-
<i>Epioblasma rangiana</i>	Northern Riffleshell	-	-	-	-	18	-	-	-	-	-
<i>Epioblasma triquetra</i>	Snuffbox	-	-	-	-	17	-	-	-	-	-
<i>Fusconaia flava</i>	Wabash Pigtoe	-	-	-	-	1	-	-	-	-	-
<i>Lampsilis cardium</i>	Plain Pocketbook	1	15	-	-	1	-	-	-	-	-
<i>Lampsilis fasciola</i>	Wavyrayed Lampmussel	-	S (2)	4	-	-	-	-	-	-	-
<i>Lampsilis siliquoidea</i>	Fatmucket	-	4	19	-	-	-	-	-	-	-
<i>Lasmigona complanata</i>	White Heelsplitter	-	-	9	-	4	-	-	-	-	-
<i>Lasmigona compressa</i>	Creek Heelsplitter	-	-	-	9*	-	-	-	-	-	-
<i>Lasmigona costata</i>	Flutedshell	39	2	22	-	68	-	-	-	-	-
<i>Leptodea fragilis</i>	Fragile Papershell	16	-	-	-	1	-	-	-	-	-
<i>Ligumia recta</i>	Black Sandshell	22	43	-	-	4	-	-	-	-	-
<i>Obliquaria reflexa</i>	Threehorn Wartyback	S (1)	-	-	-	-	-	-	-	-	-
<i>Pleurobema sintoxia</i>	Round Pigtoe	1	2	-	-	-	-	-	-	-	-
<i>Potamilus alatus</i>	Pink Heelsplitter	10	-	-	-	2	-	-	-	-	-
<i>Ptychobranhus fasciolaris</i>	Kidneyshell	-	-	-	-	19	-	-	-	-	-
<i>Pyganodon grandis</i>	Giant Floater	1	1	-	-	-	-	-	-	-	-
<i>Quadrula quadrula</i>	Mapleleaf	5	-	-	-	3	-	-	-	-	-
<i>Strophitus undulatus</i>	Creeping	-	S (2)	2	6*	-	-	-	-	-	-
<i>Truncilla truncata</i>	Deertoe	5	-	-	-	-	-	-	-	-	-
<i>Villosa fabalis</i>	Rayed Bean	-	-	-	-	2	-	-	-	-	-
<i>Villosa iris</i>	Rainbow	V (2)	-	-	-	-	-	-	-	-	-
Total No. of live individuals		156	95	57	15	197	0	0	0	0	0
Species richness (live)		12	8	6	2	18	0	0	0	0	0
Species richness (total)		14	10	6	2	18	0	0	0	0	0
Search effort (person-hours)		7.5	12.7	10	4.5	2	3	2	2	3.66	2

\*represents a combined number of individuals as the corresponding site was visited twice; 'represents presence of Zebra Mussels



Table 6. Physical characteristics of all sites surveyed by Fisheries and Oceans Canada in 2015. Substrate types are modified from (Wentworth 1922): boulder size is >250 mm, rubble between 60-250 mm, gravel between 20-50 mm, and sand is <20 mm. “Other” includes muck, mud, silt, and detritus. Dash: data not collected.

Site	Substrate (%)					Water clarity (m)	Site length (m)	Mean width (m)	Mean depth searched (m)	Stream morphology (%)			
	Boulder	Rubble	Gravel	Sand	Other					Riffle	Run	Pool	Flat
LON-FMC-01	0	0	0	20	80	0.06	50	-	1	0	0	0	100
LON-FMC-02	0	40	10	0	50	0.06	50	-	0.25	0	0	0	100
LON-FMC-03	0	0	0	0	100	0.06	50	-	0.75	0	0	0	100
LON-FMC-04	0	0	0	0	100	0.06	50	-	0.75	0	0	0	100
LON-FML-01	0	0	0	0	100	0.052	-	-	-	0	0	0	0
LON-FML-02	0	0	20	0	80	0.156	50	-	1.3	0	0	0	0
LON-FML-03	0	0	0	0	100	0.07	50	8	1.15	0	0	0	100
LON-FML-04	0	0	0	0	100	0.042	82	13	0.91	0	0	0	100
LON-FML-05	0	0	0	15	85	0.14	100	50	1	0	0	0	0
LON-FML-06	0	0	0	25	75	0.12	-	-	1	0	0	0	0
LON-MDP-01	0	75	0	0	25	0.152	-	-	0.72	0	0	0	0
LON-MDP-02	0	0	0	0	100	0.27	30	2	0.65	0	0	0	0
LON-MDP-03	0	0	5	35	60	0.164	17.5	7	0.525	0	0	0	0
LON-MDP-04	10	7.5	5	5	72.5	0.26	17.5	-	0.68	0	0	0	0
LON-MDP-05	0	0	0	0	100	0.47	25	7	0.83	0	0	0	0
LON-MDP-06	0	0	0	2.5	97.5	0.28	17.5	-	7.55	0	0	0	0
LON-MDP-07	2.5	27.5	12.5	0	57.5	0.39	20	4	0.755	0	0	0	0
LON-MDP-08	47.5	22.5	22.5	7.5	0	0.6	15	-	0.7	0	0	0	0
LON-CTP-01	0	0	0	0	100	-	119	-	0.65	0	0	0	0
LON-CTP-02	0	0	5	5	90	-	82	15	0.55	0	0	0	0
LON-CTP-03	0	0	2.5	2.5	95	0.15	105	20	0.5	0	0	0	0
LON-CTP-04	0	0	0	0	100	-	130	25	0.65	0	0	0	0
LON-CTP-05	0	0	2.5	2.5	95	-	38	6	-	0	0	0	0
LON-CTP-06	0	0	15	15	70	0.19	146.5	10	-	0	0	0	0
LON-CTP-07	0	0	0	0	100	0.21	-	10	0.5	0	0	0	0
LON-CTP-08	0	0	2.5	2.5	95	-	75.9	10	-	0	0	0	0
LON-SPC-01	0	0	3	3	94	0.35	153.1	24	-	0	100	0	0
LON-SPC-02	0	0	0	0	100	-	112	35	-	0	100	0	0
LON-SMC-NIAGARA-05	0	0	10	10	80	0.05	436.5	7	0.75	5	25	0	70
LON-SMC-NIAGARA-21	0	0	10	20	70	0.66	50	50	1	0	0	0	0
LON-SMC-NIAGARA-22	0	0	0	0	100	-	-	-	-	0	0	0	0
GR-06	25	40	20	10	5	-	119.5	73	0.3	0	100	0	0
LER-GRR-01	0	20	60	5	15	0.417	343	40	0.3	0	100	0	0
GRR-SPD-01	10	50	30	10	0	0.6	80	33	0.53	40	60	0	0
LON-CRR-17	0	10	20	40	30	0.6	200	6	0.25	30	50	20	0
SR-17	-	-	-	-	-	-	-	-	-	-	-	-	-
LON-BTE-13	0	0	0	0	100	0.31	58	35	1.5	0	0	0	100
LON-BTE-14	20	35	25	5	15	0.6	204	21	1.08	65	20	15	0
LON-BTE-15	10	30	15	0	45	0.6	145.5	18	0.76	100	0	0	0
LON-SMC-HALTON-12	40	25	25	5	5	0.44	375	24	0.49	90	10	0	0
LON-SMC-HALTON-13	30	10	5	0	55	0.42	295	-	0.32	100	0	0	0

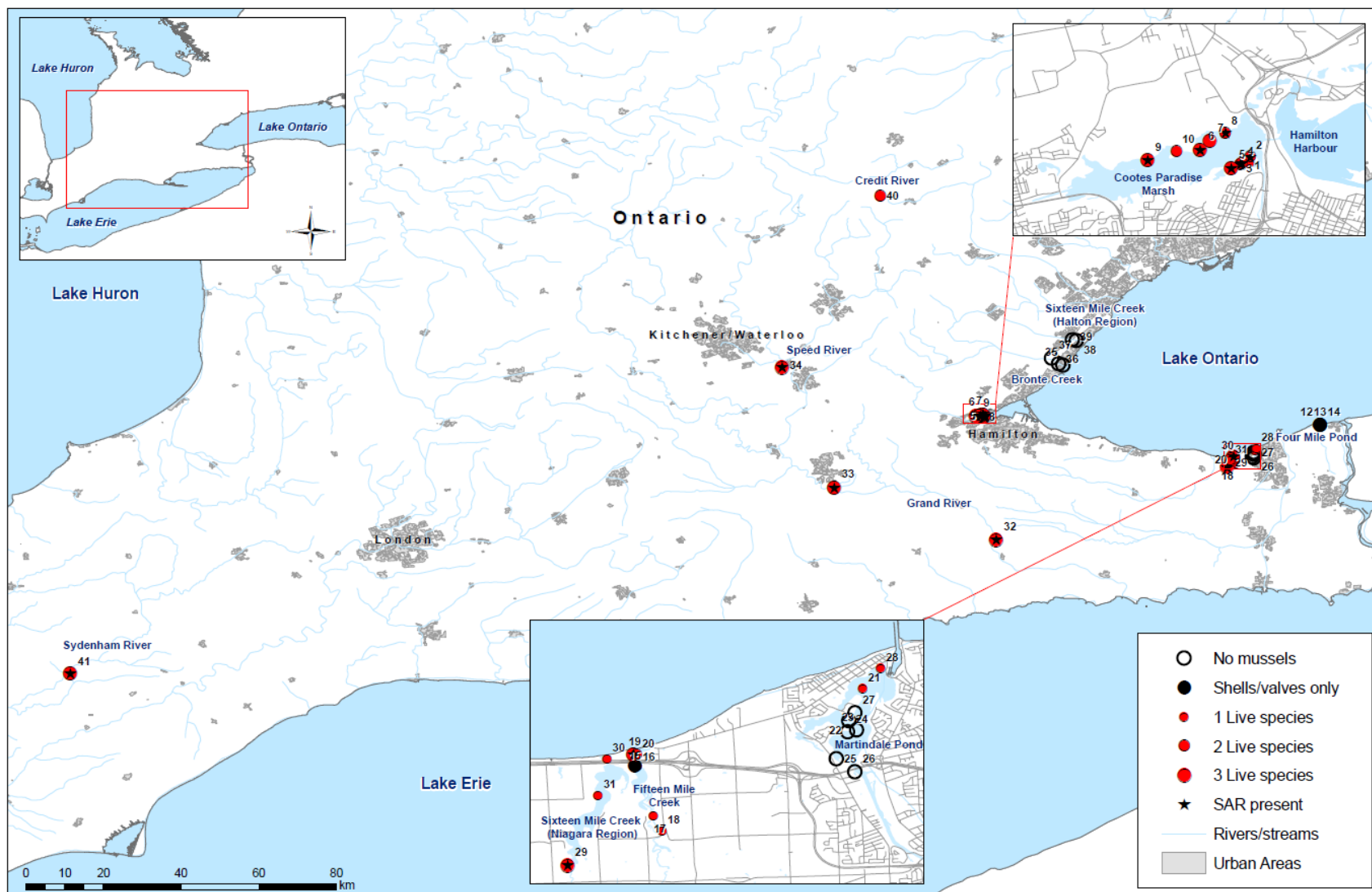


Figure 1. All sites sampled by Fisheries and Oceans Canada in 2015. Numbers correspond to site codes in Table 2.

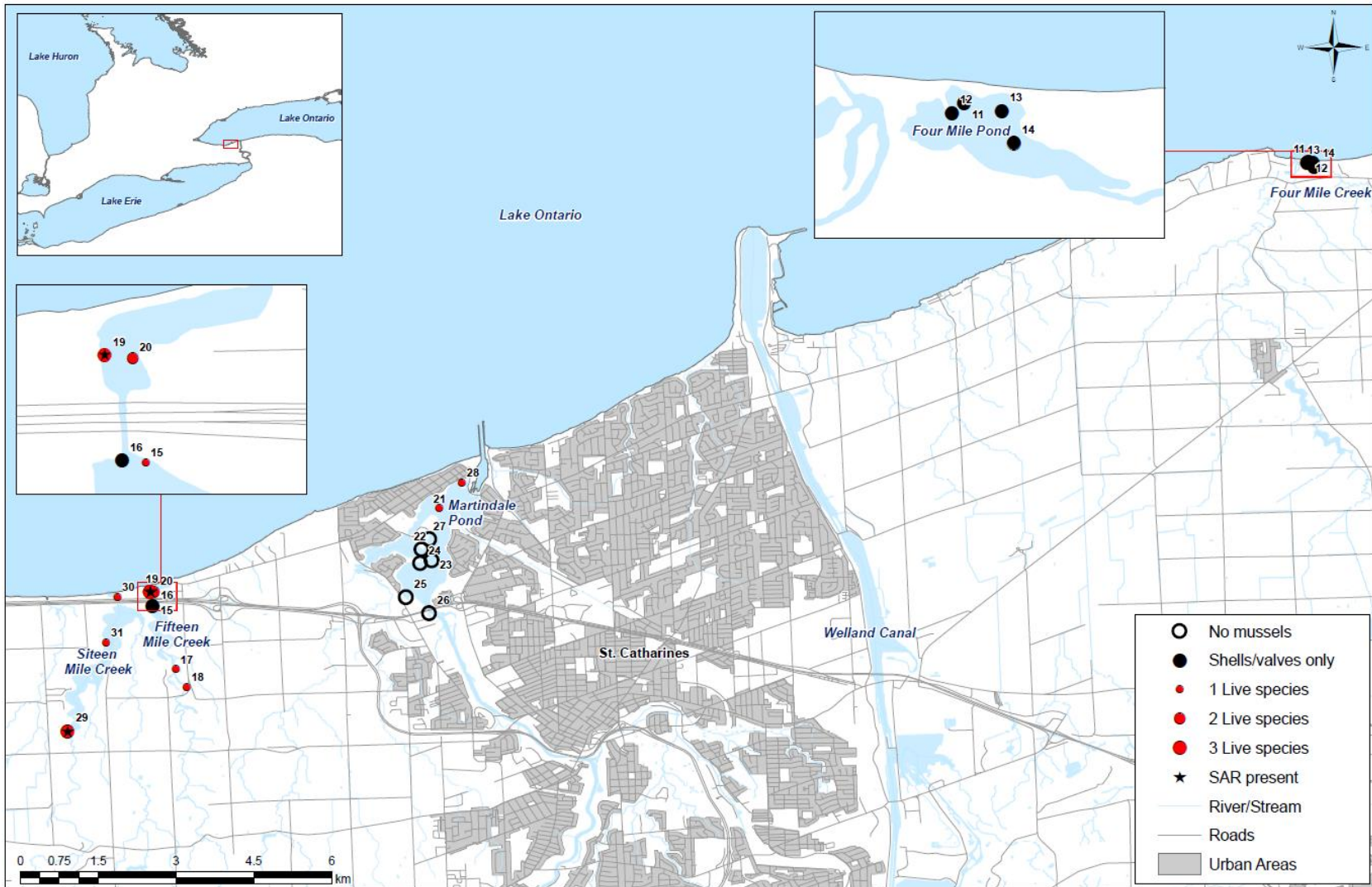


Figure 2. Lake Ontario coastal wetland sites sampled by Fisheries and Oceans Canada in 2015: Four Mile Creek, Fifteen Mile Creek, Sixteen Mile Creek-Niagara, and Martindale Pond. Numbers correspond to site codes in Table 2.

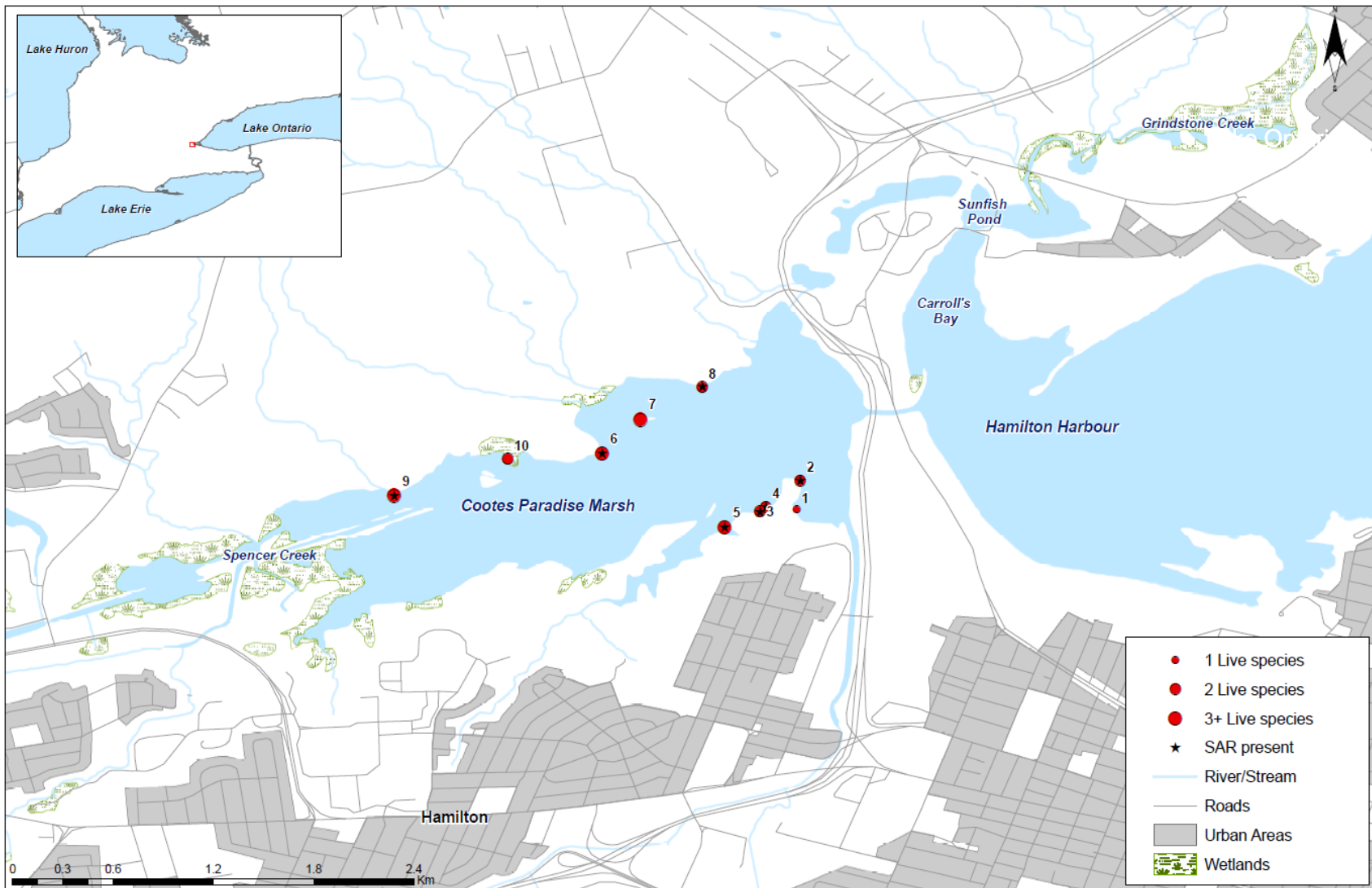


Figure 3. Cootes Paradise Marsh sites sampled by Fisheries and Oceans Canada in 2015. Numbers correspond to site codes in Table 2.

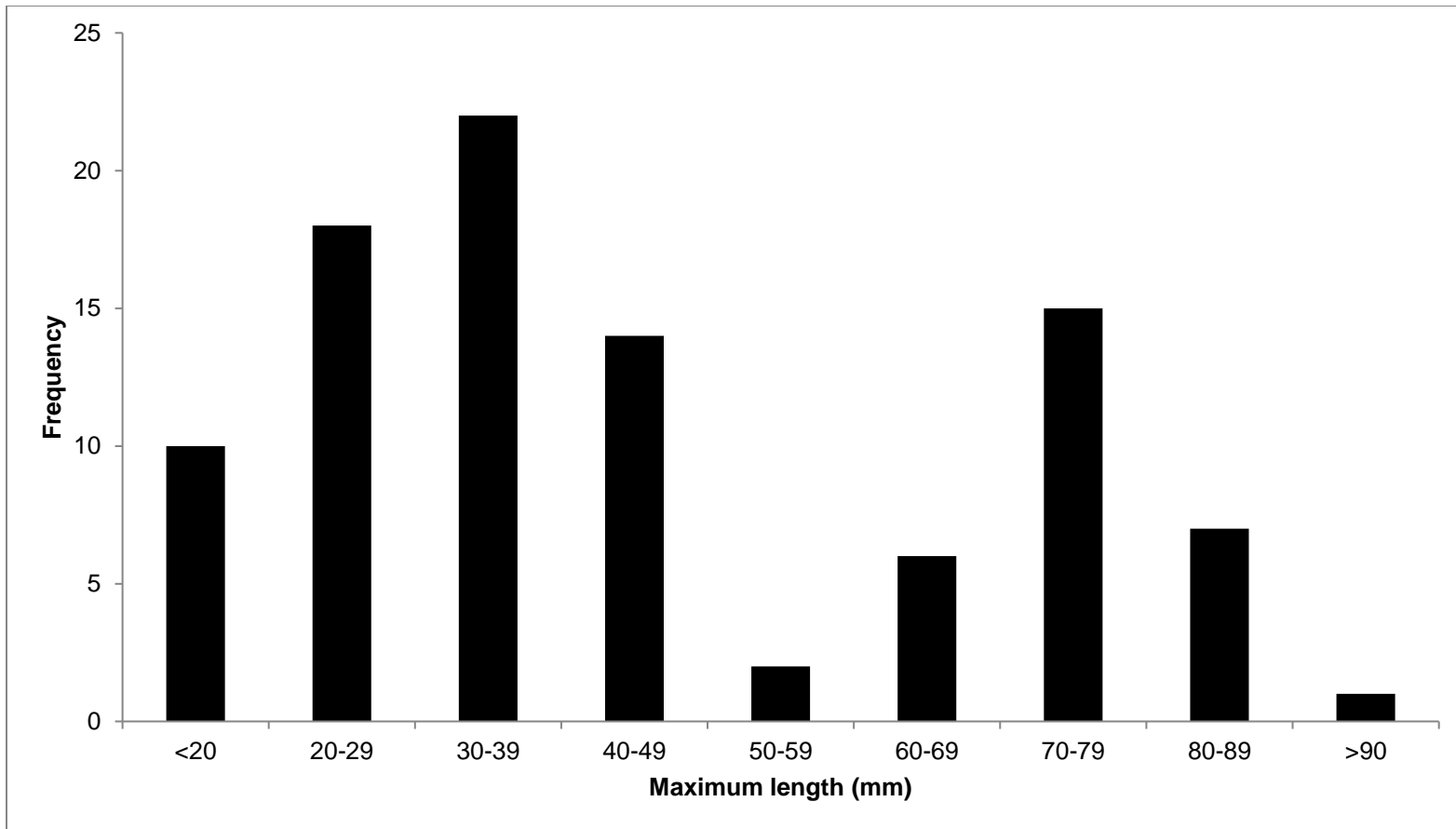


Figure 4. Length distribution of *Utterbackia imbecillis* (Paper Pondshell) collected from Cootes Paradise Marsh and Spencer Creek (n = 95).

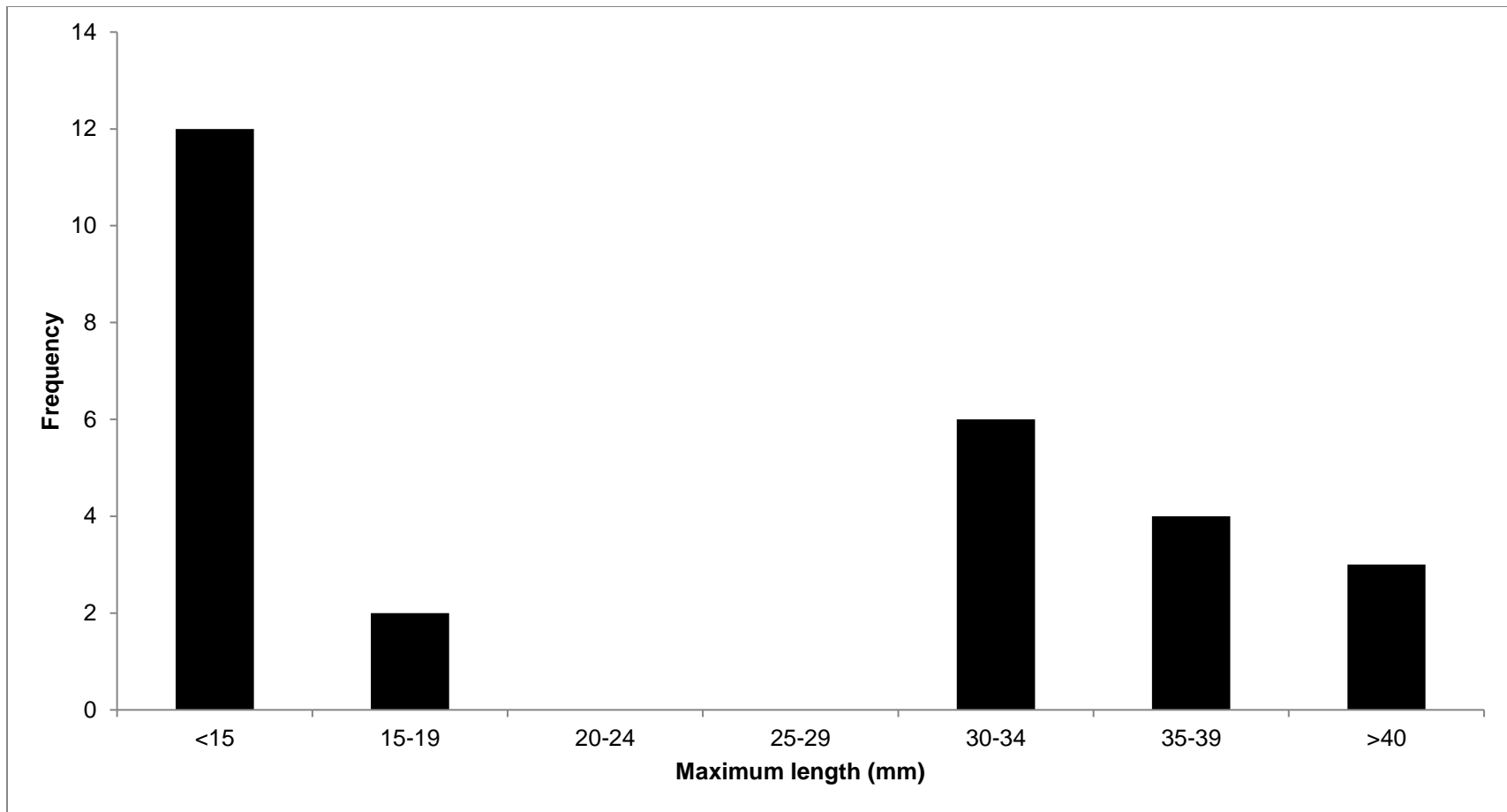


Figure 5. Length distribution of *Toxolasma parvum* (Lilliput) measured from Cootes Paradise Marsh and Spencer Creek (n = 27).



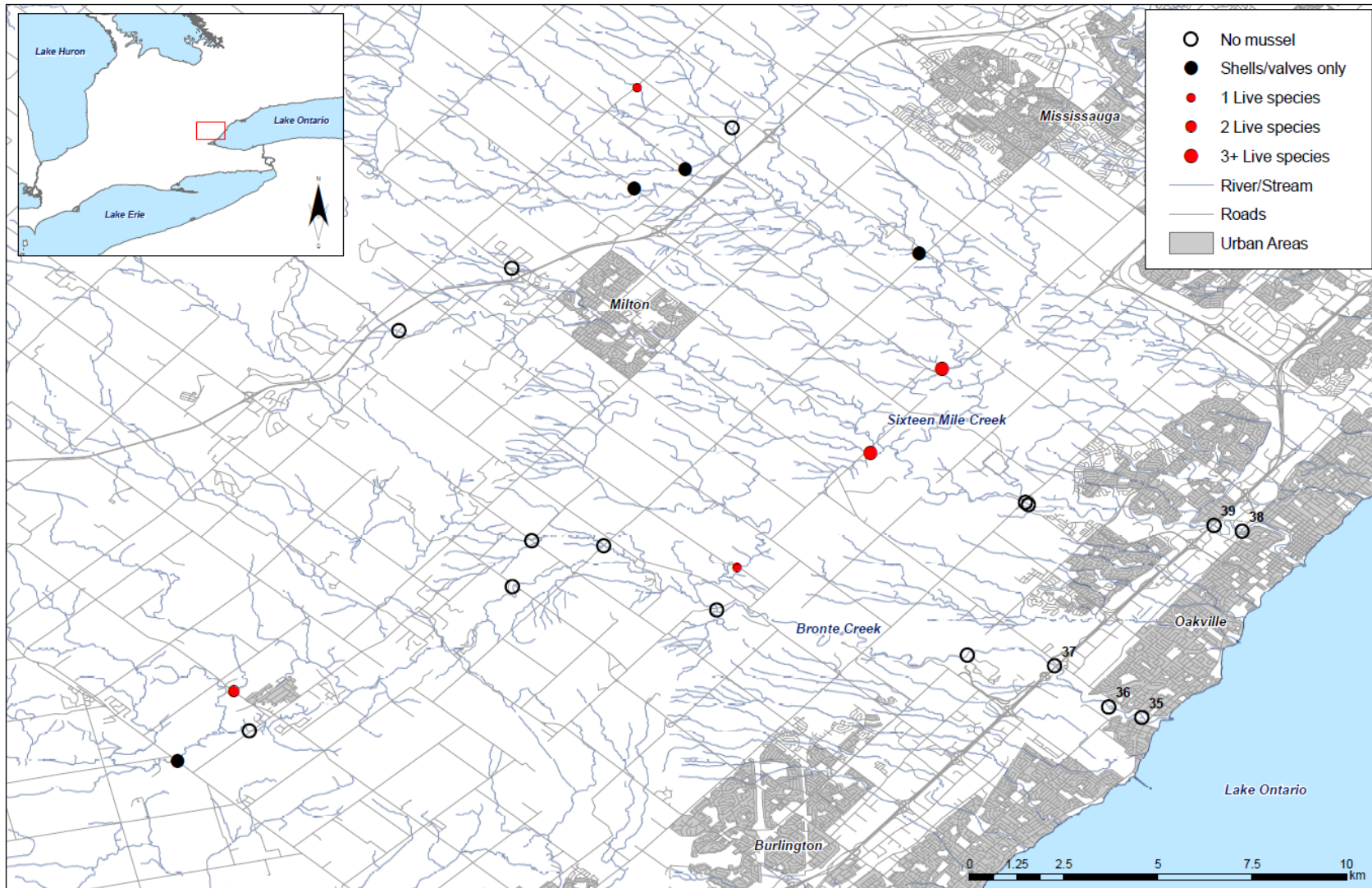


Figure 6. Numbered sites represent the Bronte Creek and Sixteen Mile Creek-Halton sites sampled by Fisheries and Oceans Canada (DFO) in 2015 (see Table 2). Records for all sites with no numbers were from DFO in 1996 with the exception of one from D. Berg in 1987 (Lower Great Lakes Unionid Database 2016).