Freshwater mussel surveys of the Welland River watershed: 2014-16

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ABSTRACT

Fisheries and Oceans Canada surveyed the Welland River in 2014, 2015, and 2016 for freshwater mussels (Unionidae). From the 19 sites surveyed within the main channel and four tributaries (Coyle, Lyons, and Oswego creeks, and the Feeder Canal), 668 live individuals representing 11 species, including three Species at Risk (SAR), were found. Additionally, one SAR and three common species were found as valves only. *Quadrula quadrula* was most abundant (433 individuals, 64.82% relative abundance). *Pyganodon grandis* most frequently occurred (57.89% of sites). Invasive *Dreissena polymorpha* were observed at six sites (31.58%). The known range of *Q. quadrula* was extended in the main channel of the Welland River and in Coyle Creek. The range of *Toxolasma parvum* was extended in the main channel and into Oswego Creek. *Ligumia nasuta* was found for the first time in this watershed, specifically in Coyle Creek. Future research will benefit from quantitative sampling techniques to eliminate biases of qualitative surveys, surveying headwaters, and revisiting sites in order to better understand population trends of both SAR and common mussel species.

RÉSUMÉ

Le personnel de Pêches et Océans Canada a enquêté la rivière Welland en 2014, 2015, et 2016 pour les moules d’eau douce (famille des unionidés). Des 19 sites sur le canal principal et les quatre affluents (ruisseaux Coyle, Lyons, et Oswego, et le Canal Feeder), 668 animaux vivants représentant 11 espèces, incluant trois en péril, ont été découverts. Soupapes d’une autre espèce en péril et trois espèces communes ont été découvertes aussi. *Quadrula quadrula* était l’espèce la plus abondante (433 animaux, 64.82% abondance relative). *Pyganodon grandis* a été constatée à 57.89% des sites et alors était la plus largement répandue. La *Dreissena polymorpha* envahissante a été observée à six sites (31.58%). La distribution qu’on sait de Q*. quadrula* a été étendue dans le canal principal et le ruisseau Coyle et celle de *Toxolasma parvum* a été étendue dans le canal principal et le ruisseau Oswego. *Ligumia nasuta* a été trouvée pour la première fois dans ce bassin versant, en particulier dans le ruisseau Coyle. La recherche future bénéficiera des enquêtes quantitative pour éliminer les biais des enquêtes qualitative, l’évaluation des cours supérieurs, et le ressassement des sites examinées pour déterminer les tendances démographiques des moules communes et en péril.

1.0 INTRODUCTION

The Central Welland River watershed is a unique watershed with rich cultural history, ecological diversity, and agricultural and recreational opportunities. It borders West Lincoln Township, Pelham, Welland, and parts of Wainfleet and Port Colborne, Ontario (NPCA 2010). The region lies within the Haldimand Clay Plain, which was submerged by post-glacial Lake Warren and covered by lacustrine clay deposits (NPCA 2010). The Welland River itself, which is 142 km long, flows east from Ancaster through the Niagara Peninsula to the Niagara River (NPCA 2010) and into Lake Ontario (Figure 1).

Extensions of the river include many tributaries, some natural and some man-made. Coyle Creek is a small, natural creek running through the towns of Welland, Pelham, and West Lincoln. Lyons Creek is also natural and runs through Niagara Falls and Welland. Portions of both creeks are classified as critical fish habitat (NPCA 2010); however, NPCA (2012a, 2012b) determined water quality to be impaired based on the pollutant tolerant benthic animals observed. Oswego Creek in Dunnville is a natural creek maintained for floodplain management (NPCA 2015). The Feeder Canal makes up one of two canals associated with the First Welland Canal which opened in 1829 (Jackson 1997); it artificially connects the lower Grand River near Port Maitland and the Welland Canal above Welland (Hughes 2007) and runs through many wetlands (NPCA 2010). The other canal is the main canal, which links Lake Ontario with the Welland River at Beverly (later Port Robinson) (Hughes 2007).

Previous records, including historical observations beginning in 1885, indicate the presence of 28 mussel species within or just beyond the greater Niagara Peninsula Conservation Authority boundary (Lower Great Lakes Unionid Database 2016; Table 1, Figure 1). Eleven of these species were reported in the Welland River between 1926 and 1988; however, the sampling details associated with these records are unknown. In 2008, preliminary surveys of the Welland River were conducted by Fisheries and Oceans Canada (DFO) in order to determine the mussel species present in the main channel of this river. A total of eight sites were surveyed and 50 live individuals representing nine species, including two Species at Risk (SAR) (*Quadrula quadrula* and *Toxolasma parvum),* were observed (Morris et al. 2012b; Table 1, Figure 1). The objective of the current study was to explore this system further, specifically to:

(1) Create mussel inventories of sites that had never been surveyed, including additional sites on the main stem of the Welland River and its tributaries (Coyle, Lyons, and Oswego creeks and the Feeder Canal)

(2) Determine or confirm the range of mussel SAR that have previously been found within the system by revisiting two sites: LON-WLR-05 and LON-WLR-02.

LON-WLR-05 was surveyed in 2014 in search of *Q. quadrula* for genetic samples and again in 2016 after a potential live *Truncilla donaciformis* was photographed in 2014. This species has been assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The 2016 surveys targeted *T. donaciformis* habitat in an attempt to confirm its presence in the Welland River.

LON-WLR-02 was resurveyed in 2015 because of its vicinity to LON-WLR-05 and the presence of *Q. quadrula* in the area.

2.0 METHODS

Timed-search sampling was completed using methodology and equipment similar to Metcalfe-Smith et al. (2000). Clear water allowed for visual techniques (naked eye and viewing boxes), while turbid waters required tactile techniques. Additionally, mussel scoops consisting of a 122 cm (4 ft) long handle, and a fine, 7 mm mesh screen were used to sample deeper areas and target juveniles (Morris et al. 2012b). A team with a minimum of three people searched each site, moving in an upstream direction that was generally parallel to the river bank. All live animals were collected and placed in a mesh diver's bag. After searching for the allotted time, all mussels were identified, measured, and sexed if possible, before being released. Surveys varied in effort, measured by time in person hours, based on the presence or absence of shells and live animals. A site was searched for 1.5 person hours if no shells or live individuals were observed during that time. If shells were observed within the initial 1.5 person hours of searching, the survey continued to 2.25 person hours but not beyond that if no live individuals were observed. If live individuals were observed at any time during the survey, search effort was continued to the standard 4.5 person hours as suggested by Metcalfe-Smith et al. (2000).

Physical and environmental variables were also recorded at each site: substrate composition was estimated visually, while water clarity, length and width of reach, and mean depth were measured using a turbidity tube, a range finder (Nikon Laser 1200S), and a metre stick/measuring tape, respectively. Definitions of substrate sizes were adapted from Morris et al. (2012b), which were modified from Wentworth (1922): boulder (>250 mm in diameter), rubble (60-250 mm), gravel (20-50 mm), sand (<2 mm), and "other" material (mud, muck, silt, and detritus).

3.0 RESULTS

3.1 FRESHWATER MUSSEL COMMUNITY

Between July 17, 2014 and June 2, 2016, 22 surveys were completed at 19 sites in the Welland River watershed (Table 2, Figure 1). Standard timed-searches ranged from 1.5 to 21.5 person hours of searching per site based on observations and survey targets (mean: 4.4 person hours; Table 3).

A total of 668 live mussels representing 11 species, including three SAR, were collected at 14 different sites (Table 3, Figure 2). A further four species, including one SAR (listed as Endangered under the *Species at Risk Act,* SARA), were found only as shells/valves. For sites where no live mussels of a given species were found, shells and valves were recorded; for sites where live mussels and shells and/or valves of the same species were found, only live were noted.

Total live abundance varied from zero at three sites to 319 at one site. Live species richness ranged from zero to seven species. The site with the highest abundance also had the highest live species richness and was located on the main branch of the Welland River (LON-WLR-05). The second highest live species richness (five) occurred at WLR-COY-01 in Coyle Creek and LON-WLR-13 on the main branch of the Welland River. These two sites had abundances of 41 and 44 individuals, respectively.

The most abundant species was *Q. quadrula* with 433 individuals observed (64.82% relative abundance). Although 60.3% of individuals were found at one site (LON-WLR-05), its frequency of occurrence was the second highest (47.37%), occurring live at nine of 19 sites. *Pyganodon grandis*, a common species, had the highest frequency of occurrence (57.89%), occurring live at 11 sites. It was the third most abundant species (72 individuals, 10.78% relative abundance), closely following *Lampsilis siliquoidea*, which was the second most abundant species (75 individuals, 11.23% relative abundance, 26.32% frequency of occurrence).

The invasive *Dreissena polymorpha* (Zebra Mussel) was observed at six of the 19 sites (31.58%) located in the main channel of the Welland River, Coyle Creek, and the Feeder Canal (Table 3, Figure 3).

Shell lengths are presented for the two most abundant SAR and two most abundant common species: *Q. quadrula*, *T. parvum*, *P. grandis* and *L. siliquoidea* (Figures 4-7). The Shapiro-Wilks test detected a normal distribution of lengths for *P. grandis* ($W=0.98$, $p=0.21$), but not for *Q. quadrula* ($W=0.99$, $p=0.0003$), *T. parvum* ($W=0.44$, $p<0.0001$), or *L. siliquoidea* ($W=0.90$, $p<0.0001$). Additionally, the lengths of the six *Ligumia nasuta* ranged from 64 – 102 mm. *Lampsilis siliquoidea* was the only sexually dimorphic species with a total of 54 males and 20 females (and one unknown) being observed, yielding a male to female sex ratio of 2.7:1. Chi-square test results showed that there were significantly more males than females ($\chi^2_{0.05,\,1}=15.62$, $p<0.0001$).

Two sites (LON-WLR-02 and LON-WLR-05) that were originally surveyed in 2008 were resurveyed in 2014-16. LON-WLR-05 was resurveyed twice, once in 2014 and again in 2016. More individuals were found in the 2014-16 surveys than in 2008 (Table 4), but no statistical or definite conclusions could be drawn due to differences in survey objectives.

3.2 ABIOTIC FACTORS

The physical data from each sampling site in the Welland River watershed is summarized in Table 5. This collection 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 mean values presented below as some data were not collected during sampling. Generally, the substrate was fine-textured, with at least 50% “other” material (muck, mud, silt, and detritus) observed at 14 of the 19 sites where data were collected. This was reflected in the water clarity as mean visibility was 0.21 m. Site length and mean width ranged from 22.5 to 195 m and 4.13 to 68.5 m, respectively. Mean depth surveyed was approximately 0.60 m. Stream morphology was 100% flat at 13 of the 19 sites.

4.0 DISCUSSION

4.1 LIVE SAR OCCURRENCES

A total of 11 live species were observed in the Welland River watershed during the 2014-16 sampling events. Two of these, *L. nasuta* and *Q. quadrula,* are listed under SARA as Endangered and Threatened, respectively. In addition, *T. parvum* has been assessed as Endangered by COSEWIC and is under consideration for listing under SARA.

In Ontario, *Q. quadrula* has lost 49% of its former range due to threats of Dreissenid (*Dreissena polymorpha* and *D*. *bugensis*) mussels, pollution, and habitat degradation from agricultural and urban activities (COSEWIC 2006). This species still occurs in parts of its historic waterbodies of lakes Erie and St. Clair as well as the Sydenham, Grand, Welland, Thames, and Niagara rivers; however, it has also been observed in a number of additional waterbodies since 2013, including lakes Huron (Ausable and Bayfield rivers, and Cow and Perch creeks), St. Clair (Ruscom and Puce rivers, and Baptiste and McGregor creeks), Erie (Lake Henry (Pelee Island) and Rondeau Bay), and Ontario (Welland River watershed and coastal wetland areas) (Lower Great Lakes Unionid Database 2016; Morris et al. 2012a, 2012b). Recently, COSEWIC has reassessed *Q. quadrula* in the Great Lakes-Upper St. Lawrence as Special Concern (Government of Canada 2016).

In the Welland River, *Q. quadrula* was first observed in 1983 as shells (Lower Great Lakes Unionid Database 2016). The first live observation occurred in 2008 when targeted SAR surveys were conducted by DFO (Morris et al. 2012b). Conservation genetics techniques were used to elucidate the likely invasion history of *Q. quadrula* into the Lake Ontario watershed. Results suggested that this species entered during the first iteration of the canal by way of a connection between the Lower Grand, Welland River, and Lake Ontario; this suggests that *Q. quadrula* has been in the Welland River since at least 1833 (Hoffman 2016).

In addition to collecting genetic samples, a total of 433 live *Q. quadrula* were observed during the 2014-16 surveys, generating new records in sections of the main branch of the Welland River, as well as Coyle and Oswego creeks and potentially the Feeder Canal. As these tributaries had not been previously surveyed, it is unknown if these data represent survey effort or population expansion. *Quadrula quadrula* also appear to be successfully reproducing in the Welland River watershed as small individuals (9 – 15 mm) were observed during the current surveys (Figure 4). These surveys have provided more information on the range and population status of *Q. quadrula* in the Welland River watershed.

Toxolasma parvum has been lost from 44% of its former range in Canada; threats include invasive Dreissenid mussels, pollution from urban development, and sedimentation (COSEWIC 2013). Historically, *T. parvum* was found in the tributaries of lakes St. Clair and Erie as well as the Detroit River (COSEWIC 2013). Currently, it is confined to the tributaries of Lake St. Clair (e.g., Belle, Ruscom, Sydenham, and lower Thames rivers), Lake Erie (Grand River and Pelee Island), and Lake Ontario (Hamilton Harbour (Sunfish Pond), Jordan Harbour, Cootes Paradise, and Welland River)

(COSEWIC 2013; Lower Great Lakes Unionid Database 2016). The first live specimen found in the Welland River, and thus in the Niagara Region, was in 2008 (Lower Great Lakes Unionid Database 2016). Surveys in 2015 found 18 live individuals at six sites in the Welland River watershed, including Oswego Creek; however, a larger sample size via continued study is required to determine the reproductive success of this species.

Ligumia nasuta was one of the most common freshwater mussel species in the lower Great Lakes preceding *Dreissena polymorpha* invasion in the 1980s; 90% of its historical records are in waters that now contain this invasive species (COSEWIC 2007). *Ligumia nasuta* has decreased in abundance, but its current distribution still resembles its historical range (COSEWIC 2007). This species is currently found in a number of places, including the St. Clair River delta, coastal wetland areas of lakes Erie and Ontario, as well as eastern Ontario inland lakes and Lyn Creek which flows into the St. Lawrence River (Lower Great Lakes Unionid Database 2016). In the 2014-16 surveys, six *L. nasuta* were found at two sites (WLR-COY-01, WLR-COY-02), generating the first live records of this species in Coyle Creek and, thus, the Welland River watershed.

Importantly, *T*. *donaciformis*, which has been assessed by COSEWIC as Endangered and is under consideration for listing under SARA, requires further study throughout the entirety of its current distribution. An individual collected from the Welland River in 2016 initially identified as *Truncilla donaciformis* using morphological characteristics, has recently been confirmed as *T*. *truncata* (C. Currier, Trent University, Peterborough, ON K9L 0G2, pers. comm.). Therefore, there appears to be morphological similarities between the two *Truncilla* species (*T*. *donaciformis* and *T*. *truncata*) in Canada. Further morphological and genetic research is required to determine if *T. donaciformis* is present in the Welland River watershed and to confirm its Canadian distribution in light of the genetic and morphological discrepancy reported here. This species has been reported historically in the Niagara River (unknown if live or shell) and shells have been collected from the Feeder Canal by Schueler (2012) in 2008 and DFO in the current study. However, these records should be interpreted with caution due to the morphological similarities between the two *Truncilla* species.

4.2 VALVE OCCURRENCES IN THE FEEDER CANAL

A brief overview of the history of the Feeder Canal is essential to interpret the results of the 2015 surveys. The Feeder Canal represents an approximately 30 km long artificial connection between the lower Grand River near Port Maitland and the Welland Canal above Welland (Hughes 2007). It was initially constructed in 1829 to bolster water levels in the First Canal with input from the Grand River, but soon became a primary avenue for the transport of commercial goods between the Grand and Welland rivers (Jackson 1997). The Feeder Canal was enlarged in 1845 to accommodate alterations made to the First Canal, termed the Second Canal, which allowed easier access to Lake Ontario for large vessels. The Feeder Canal remained highly operational from the time of its opening until 1881, following the creation of the Third Canal which no longer required external input for increased water levels, and remained in disuse when the Fourth Canal (current iteration) was built in 1932 (Jackson 1997). After its closing, the

Feeder Canal became increasingly segmented as embankments were built to allow easy crossing over the canal, preventing flow and creating stagnant sections within the once flowing channel. In 1944, culverts were added to the embankments to improve drainage and reduce stagnation (Jackson 1997). Despite these additions, the Feeder Canal currently remains a series of disconnected stagnant ponds and no longer serves as a direct connection between the Grand River and Welland Canal (Figure 8). For over five decades, the Feeder Canal facilitated the movement of people throughout the Niagara Region, but could also have provided a means for freshwater mussels to travel, via host fish, between the Grand and Welland rivers.

Surveys of the Feeder Canal conducted in 2008 by Schueler (2012) and in 2015 by DFO generated shell records for 10 mussel species, including three SAR (Table 6). While it is possible that these species did exist in the Feeder Canal, the collection results, especially those at site WLR-FED-02, should be interpreted with caution. Specimens found at this site in 2015 were collected from an area of apparent fill material adjacent to the canal (Figure 9). The exact origin of this material and the shells contained within cannot be positively attributed to the Feeder Canal at this time (Brydon MacVeigh, Fisheries and Oceans Canada, 867 Lakeshore Rd., Burlington, Ontario, L7S 1A1, pers. comm.). However, all species collected as shells/valves from the Feeder Canal are currently or historically known from the Grand and/or Welland rivers (McNichols-O'Rourke et al. 2012; Morris et al. 2012b) and could have occurred within this system.

A short discussion is provided on the shells observed in the Feeder Canal during both sampling events. Schueler (2012) surveyed an area near Stromness between WLR-FED-04 and WLR-FED-03 (Figure 10); shells of two common species (*Amblema plicata* and *P. grandis*) and three SAR (*Q. quadrula, T. parvum*, and *T. donaciformis)* were found. The same uncertainties associated with the *Truncilla* species in the main stem of the Welland River apply to shell records from the Feeder Canal. Therefore, the *T*. *donaciformis* records need to be interpreted with caution and as such are included in this report as *Truncilla* sp. At a second site near Wainfleet, between WLR-FED-03 and WLR-FED-02, Schueler (2012) observed two weathered Unionid valves on the bank of the canal. All five of the species found by Schueler (2012) were also found by DFO in 2015 at either WLR-FED-02 or WLR-FED-04. DFO also observed valves of an additional five common species (*Actinonaias ligamentina, Lasmigona costata, Leptodea fragilis, Potamilus alatus,* and *Truncilla sp.*) and one SAR (*Ptychobranchus fasciolaris*).

Collectively, three valves of SAR were observed in the Feeder Canal: *P. fasciolaris*, *Q. quadrula, T. parvum*. *Truncilla donaciformis* could be considered a fourth SAR. Specific details for the latter three SAR are included in Section 4.1. For *P. fasciolaris,* it is currently restricted to the East Sydenham and Ausable rivers, St. Clair River delta, and Medway Creek (Thames River tributary) (COSEWIC 2003). Shells or valves have also been previously observed in the Niagara, Welland, and Grand rivers (Lower Great Lakes Unionid Database 2016; Table 6). Therefore, all four SAR have been recorded alive or as shells in both the Grand and Welland rivers.

The remaining valves represented seven common species (Table 3, Table 6), all of which have been observed alive or as shells in the Grand River (Lower Great Lakes Unionid Database 2016). In the Welland River, four of the species have been observed alive and one, *A. plicata*, was observed as shells during the current study. Two of the species, *A. ligamentina* and *L. costata,* have no live or shell records in the Welland River (Lower Great Lakes Unionid Database 2016).

4.3 COMMON SPECIES' OCCURRENCES

As shell lengths of *P. grandis* individuals followed a normal distribution, reproductive success is suggested for this population (Figure 6). Shell lengths for *L. siliquoidea* individuals did not follow a normal distribution (Figure 7). There were few individuals with small shell lengths, which could suggest low recruitment levels limiting population growth (Haag and Warren 2007) or be the result of the survey design. Timed-search surveys are generally biased towards larger individuals compared to smaller ones as the technique is based on visual and tactile surveys (Strayer and Smith 2003). Although this poses a possible explanation for the *L. siliquoidea* trend, it was not seen in other species where wider length frequency distributions were found (e.g., *P. grandis*).

In addition, the male-biased sex ratio of the *L. siliquoidea* population may be an indication of the natural population sex ratio. Sex ratios vary among mussel species and populations have been observed as male-biased in some lampsiline species (Haag 2012). It could also be an artifact of the time of year when sampling occurred or the natural vertical migration of the population. Vertical migration has been observed to correlate with day length and temperature (*L. siliquoidea*; Perles et al. 2003), as well as reproduction (*Lampsilis fasciola;* Todd Morris, pers. obs.).

Other notable common species were *Utterbackia imbecillis,* which was found at multiple sites in 2015-16 after being first observed in the Welland River in 2008 (Morris et al. 2012b). A single live *Lasmigona compressa* was found in Lyons Creek in 2015, representing the first live record for this species in the Welland River watershed and the Niagara Region. It was historically found just outside the Niagara Region in New York; however, there are few details associated with this record (Lower Great Lakes Unionid Database 2016). For all other species not discussed above, observations of individuals in 2014-16 surveys were concurrent with those in 2008 (Morris et al. 2012b).

4.4 SITES REVISTED

Two sites were revisited over time, but no definite conclusions can be drawn due to differing survey objectives between 2008 and 2014-16. For LON-WLR-02, species abundance and richness were higher in 2015 than in 2008 when no species were found, though both were still low. For LON-WLR-05, abundance was high in all three survey years and increased over time, though species richness decreased between 2008 and 2014 before increasing again in 2016. This could be an artifact of the sampling techniques, water levels, and/or the time of year when sampling occurred. However, as the purpose of the 2014 survey was to obtain genetic samples of *Q. quadrula*, it is probable that more species or individuals may have been observed, but not recorded.

To monitor changes in species richness and abundance over time, it would be beneficial to sample the same sites in subsequent years, using a quantitative sampling method. Data collected from the 2014-16 surveys, as well as those in 2008 (Morris et al. 2012b), could be used to determine suitable sites for monitoring.

4.5 CONCLUSION

In conclusion, the sampling of 19 sites in the Welland River watershed in 2014-16 resulted in the observation of 668 live individuals representing a total of 11 species (three SAR), with an additional four species (one SAR) found as shells/valves. The first objective of this study was to inventory areas within the Welland River watershed that had not been previously surveyed by DFO. Fifteen sites were surveyed for the first time and included sites in the main channel as well as at least one site in each of the four tributaries (Coyle, Lyons, and Oswego creeks, and Feeder Canal).

The second objective was to determine or confirm the range of certain SAR, notably *Q. quadrula* and *T. parvum,* as the first live records for these species occurred in 2008. A total of 433 live *Q. quadrula* were found, extending its known range in the main stem of the Welland River and locating new populations in Coyle Creek. Eighteen live *T. parvum* were found, extending its known range in the Welland River watershed to include Oswego Creek. *Ligumia nasuta* were found in Coyle Creek, which represents the first live occurrence of this species in the Welland River watershed (historical records are shells). These new records will assist with the protection and recovery of these imperiled species.

Future recommendations include: the use of quantitative surveys to determine density and to eliminate some of the biases associated with qualitative survey techniques, survey the headwaters of this system, and create monitoring stations to detect changes in abundance, species richness, habitat characteristics, and densities. The use of monitoring stations will be beneficial for both SAR and common species. Finally, further research, including genetics and morphometrics is required to determine the differences between the two species of the *Truncilla* in Canada.

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Table 1. Mussel species (live or shell records) occurring in the Niagara Region and Welland River watershed (x = present, - = absent) and their conservation status. Species at risk are highlighted. Assessment by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), federal Species at Risk Act *(SARA), and provincial* Endangered Species Act *(ESA) (Government of Canada 2016, Government of Ontario 2016). Unionid data from Lower Great Lakes Unionid Database (2016).*

Scientific Name	Common Name	Niagara Region	Welland River			COSEWIC (Assessment)	SARA (Federal)	ESA (Provincial)
		(1885 – 2002)	1926 - 1988	2008	2014-16			
Actinonaias ligamentina	Mucket	x*	-	-	x			
Alasmidonta marginata	Elktoe	x*	-	-	-			
Alasmidonta viridis	Slippershell Mussel	x	-	-	-			
Amblema plicata	Threeridge	x*	-	-	x			
Amphinaias pustulosa	Pimpleback	x*	-	-	-			
Anodontoides ferussacianus	Cylindrical Floater	x	-	-	-			
Elliptio complanata	Eastern Elliptio	x	-	-	-			
Elliptio dilatata	Spike	x	x	-	-			
Epioblasma triquetra	Snuffbox	x	-	-	-	Endangered	Endangered	Endangered
Fusconaia flava	Wabash Pigtoe	x	-	-	-			
Lampsilis cardium	Plain Pocketbook	x	-	-	-			
Lampsilis siliquoidea	Fatmucket	x	x	x	x			
Lampsilis radiata	Eastern Lampmussel	x	-	-	-			
Lasmigona compressa	Creek Heelsplitter	x*	-	-	x			
Lasmigona costata	Flutedshell	x	-	-	x			
Leptodea fragilis	Fragile Papershell	x	x	x	x			
Ligumia nasuta	Eastern Pondmussel	x	x	-	x	Endangered	Endangered	Endangered
Ligumia recta	Black Sandshell	x	-	-	-			
Obovaria olivaria	Hickorynut	x	-	-	-	Endangered	No status	Endangered
Obovaria subrotunda	Round Hickorynut	x	x	-	-	Endangered	Endangered	Endangered
Pleurobema sintoxia	Round Pigtoe	x	-	-	-	Endangered	Endangered	Endangered
Potamilus alatus	Pink Heelsplitter	x	x	x	x			
Ptychobranchus fasciolaris	Kidneyshell	x	x	-	x	Endangered	Endangered	Endangered
Pyganodon grandis	Giant Floater	x	x	x	x			
Quadrula quadrula	Mapleleaf	x	x	x	x	Special Concern	Threatened	Threatened
Strophitus undulatus	Creeper	x	x	x	x			
Toxolasma parvum	Lilliput	-	-	x	x	Endangered	No status	Threatened
Truncilla sp.^	Fawnsfoot or Deertoe	x	x	x	x			
Utterbackia imbecillis	Paper Pondshell	-	-	x	x			
Villosa iris	Rainbow	x	-	-	-	Special Concern	Endangered	Threatened
Total Species Richness		28	11	9	15			

* Just outside Niagara Region boundary.

^ *Truncilla donaciformis* has been assessed by COSEWIC, and listed under the ESA, as Endangered and is under consideration for SARA listing. *Truncilla truncata* has not been assessed.

Table 2. Site descriptors and collectors for all Welland River watershed sites surveyed from 2014-16 by Fisheries and Oceans Canada. Labels correspond to those in Figures 1-3.

Site	Date	Latitude	Longitude	Waterbody	Local Description	Effort (person hours)	Collectors	Label
LON-WLR-02	28/05/15	43.04299	-79.68457	Welland River	Abingdon Rd. between North and South Chippawa Rd.	4.5	MacVeigh, Sheldon, Gibson	A
LON-WLR-05	17/07/14; 02/06/16	43.02093	-79.61739	Welland River	Church Rd., North of South Chippawa Rd.	12.5; 9	Epp, MacVeigh, Darcy, Sheldon, Hoffman; McNichols-O'Rourke, Gibson, Bohlender, Jones-Baumgardt	B
LON-WLR-12	28/05/15	43.02611	-79.65105	Welland River	Caistor Center Rd. near South Chippawa Rd. intersection	4.5	MacVeigh, Sheldon, Gibson	C
LON-WLR-13	28/05/15	43.05487	-79.71796	Welland River	Upstream and downstream of Caistorville Rd. crossing	4.5	MacVeigh, Sheldon, Gibson	D
LON-WLR-14	03/06/15	43.05301	-79.75294	Welland River	Westbrook Rd.	4.5	MacVeigh, Sheldon, Gibson	E
LON-WLR-15	03/06/15	43.05835	-79.76847	Welland River	Alongside Sinclairville Rd. upstream of bridge crossing	4.5	MacVeigh, Sheldon, Gibson	F
LON-WLR 16	03/06/15	42.99263	-79.56472	Welland River	Canaborough crossing	4.5	MacVeigh, Sheldon, Gibson	G
LON-WLR-17	30/07/15	43.03555	-79.18433	Welland River	Moyer Rd.	1.5	MacVeigh, Sheldon, Gibson	H
LON-WLR-18	06/08/15	42.99929	-79.47256	Welland River	Wellandport Community Park	4.5	MacVeigh, Sheldon, Gibson, Choy	I
LON-WLR-19	06/08/15	42.99291	-79.41135	Welland River	Boyle Rd. crossing	4.5	MacVeigh, Gibson, Choy	J
WLR-COY-01	25/05/15; 17/06/15	42.98038	-79.28548	Coyle Creek	S. Pelham Rd. crossing	4.5; 9	MacVeigh, Gibson, Sheldon, Schaefer, Krupp	K
WLR-COY-02	26/05/15	42.98426	-79.31075	Coyle Creek	Upstream and downstream of Effingham Rd. (Hwy 529)	5	MacVeigh, Sheldon, Gibson, McNichols-O'Rourke	L
WLR-COY-03	26/05/15	42.98867	-79.3269	Coyle Creek	Poth Rd.	4.5	MacVeigh, Sheldon, Gibson, McNichols-O'Rourke	M
WLR-FED-01	27/05/15	42.93134	-79.34823	Feeder Canal	Upstream of Overholt Rd.	1.5	MacVeigh, Sheldon, Gibson	N
WLR-FED-02	27/05/15	42.92211	-79.38066	Feeder Canal	Claredon St. with crossing near Wainsfleet	2.25	MacVeigh, Sheldon, Gibson	O
WLR-FED-03	27/05/15	42.89963	-79.4583	Feeder Canal	Wainsfleet/Dunnville Townline	1.5	MacVeigh, Sheldon, Gibson	P
WLR-FED-04	27/05/15	42.86543	-79.56696	Feeder Canal	Below Old Lock 27 in Port Maitland	2.25	MacVeigh, Sheldon, Gibson	Q
WLR-LYO-02	27/05/15	43.00673	-79.12232	Lyons Creek	Montrose Rd. crossing upstream and downstream	4.5	MacVeigh, Sheldon, Gibson	R
WLR-OSW-02	26/05/15; 31/08/15	42.97672	-79.58669	Oswego Creek	Robinson Rd.	4.5; 1.2	MacVeigh, Sheldon, Gibson, McNichols-O'Rourke	S

Table 3. Number of live specimens of each species collected at each of the 19 sites surveyed in the Welland River watershed in 2014-16. Species at risk are highlighted. S (#) = species observed as whole shells (number of shells); V (#) = species observed as valves (number of valves). Surveys were conducted at WLR-FED-01 and WLR-FED-03 for 1.5 person hours each, but nothing was found so they were not included in this table; they are included in the calculation of Frequency of Occurrence (%). For common names see Table 1.

Scientific Name	LON-WLR-02	LON-WLR-05^	LON-WLR-12	LON-WLR-13	LON-WLR-14	LON-WLR-15	LON-WLR-16*	LON-WLR-17*	LON-WLR-18*	LON-WLR-19*	WLR-COY-01*^	WLR-COY-02	WLR-COY-03	WLR-FED-02’	WLR-FED-04*	WLR-LYO-02	WLR-OSW-02^	Total Abundance	Relative Abundance (%)	Frequency of Occurrence (%)
Actinonaias ligamentina	-	-	-	-	-	-	-	-	-	-	-	-	-	V (1)	-	-	-	0	0.00	0.00
Amblema plicata	-	-	-	-	-	-	-	V (1)	-	-	-	-	-	V (1)	-	-	-	0	0.00	0.00
Lampsilis siliquoidea	S (2)	7	31	13	-	1	-	-	-	-	23	-	-	-	-	-	-	75	11.23	26.32
Lasmigona compressa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	0.15	5.26
Lasmigona costata	-	-	-	-	-	-	-	-	-	-	-	-	-	V (1)	-	-	-	0	0.00	0.00
Leptodea fragilis	-	16	S (1)	-	-	-	-	-	-	-	2	-	-	V (1)	-	-	5	23	3.44	15.79
Ligumia nasuta	-	-	-	-	-	-	-	-	-	-	4	2	-	-	-	-	-	6	0.90	10.53
Potamilus alatus	-	3	-	-	-	-	-	-	-	-	-	-	-	V (1)	-	-	-	3	0.45	5.26
Ptychobranchus fasciolaris	-	-	-	-	-	-	-	-	-	-	-	-	-	V (1)	-	-	-	0	0.00	0.00
Pyganodon grandis	1	3	17	10	2	-	-	V (1)	1	-	2	14	8	-	S (5), V (2)	4	10	72	10.78	57.89
Quadrula quadrula	1	261	19	10	-	-	18	-	12	1	10	-	-	V (1)	-	-	101	433	64.82	47.37
Strophitus undulatus	-	S(1)	V (2)	3	-	S (1), V (3)	-	-	-	-	-	-	-	-	-	-	-	3	0.45	5.26
Toxolasma parvum	-	S(1)	S (1)	8	1	1	1	-	-	1	-	-	-	V (1)	-	-	6	18	2.69	31.58
Truncilla sp.	-	22	-	-	-	-	3	-	-	-	-	-	-	V (2)	-	-	-	25	3.74	10.53
Utterbackia imbecillis	1	7	-	-	-	-	-	-	-	1	-	-	-	-	-	-	V (1)	9	1.35	15.79
Total no. individuals (live)	**3**	**319**	**67**	**44**	**3**	**2**	**22**	**0**	**13**	**3**	**41**	**16**	**8**	**0**	**0**	**5**	**122**	**668**		
Species richness (live)	**3**	**7**	**3**	**5**	**2**	**2**	**3**	**0**	**2**	**3**	**5**	**2**	**1**	**0**	**0**	**2**	**4**			
Species richness (total)	**4**	**9**	**6**	**5**	**2**	**3**	**3**	**2**	**2**	**3**	**5**	**2**	**1**	**9**	**1**	**2**	**5**			
Effort (person hours)	**4.5**	**21.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**1.5**	**4.5**	**4.5**	**13.5**	**5**	**4.5**	**2.25**	**2.25**	**4.5**	**5.7**			

**Dreissena polymorpha* present.
^Sites visited twice with numbers combined from both sampling events.
’It is not known if the shells from this site were originally from the Feeder Canal or if they were added with fill during construction in 2014.

Table 4. Mussels found in two Welland River sites that were resampled between 2008 and 2016. Species at risk are highlighted. S (#) = species observed as whole shells (number of shells). For common names see Table 1.

Scientific Name	**LON-WLR-02 (previously WR-02)**		**LON-WLR-05 (previously WR-05)**		
	2008	**2015**	**2008**	**2014**	**2016**
Lampsilis siliquoidea	-	S(2)	1	-	7
Leptodea fragilis	-	-	2	1	15
Potamilus alatus	-	-	3	-	3
Pyganodon grandis	-	1	2	-	3
Quadrula quadrula	-	1	25	58	203
Strophitus undulatus	-	-	-	-	S(1)
Toxolasma parvum	-	-	-	-	S(1)
Truncilla sp.	-	-	2	11	11
Utterbackia imbecillis	-	1	-	-	7
Unknown juvenile	-	-	1	-	-
Total no. individuals (live)	**0**	**3**	**36**	**70**	**249**
Species richness (live)	**0**	**3**	**7**	**3**	**7**
Species richness (total)	**0**	**4**	**7**	**3**	**9**
Effort (person hours)	**4.5**	**4.5**	**4.5**	**12.5**	**9**

Table 5. Physical characteristics of sites surveyed in the Welland River watershed in 2014-16. 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.

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-WLR-02	0	0	30	10	60	0.28	65.5	18	0.41	0	0	0	100
LON-WLR-05*	-	-	-	-	-	0	111	20	0.65	-	-	-	-
LON-WLR-12	25	30	30	10	5	0.38	54	11.5	0.34	15	0	85	0
LON-WLR-13	10	15	35	10	30	-	65	11	0.45	10	0	40	50
LON-WLR-14	10	5	0	0	85	0.1	67	20	0.95	0	0	0	100
LON-WLR-15	5	0	5	10	80	0.18	67.5	12	0.57	0	0	0	100
LON-WLR-16	5	20	40	20	15	0.19	22.5	13	0.86	0	0	0	100
LON-WLR-17	0	5	15	0	80	0.39	25	68.5	0.45	0	0	0	100
LON-WLR-18	0	0	0	0	100	-	107.5	55	0.85	0	0	0	100
LON-WLR-19	20	0	20	0	60	0.06	30	30.5	0.6	0	0	0	100
WLR-COY-01^	-	-	-	-	-	0.119	42	8.86	-	0	0	0	100
WLR-COY-02	0	0	5	0	95	0.09	71.5	4.13	-	0	0	0	100
WLR-COY-03	0	0	10	15	75	0.148	195	-	0.28	-	-	-	-
WLR-FED-01	0	0	0	0	100	0.178	60	17.8	0.64	0	0	0	100
WLR-FED-02	0	0	0	0	100	0.55	51	18.3	0.66	0	0	0	100
WLR-FED-03	0	0	0	0	100	0.6	33	14.75	0.61	0	0	0	100
WLR-FED-04	0	0	50	0	50	0.1	55.5	25.5	0.56	0	0	0	100
WLR-LYO-02	10	10	20	10	50	0.178	86.2	6.2	0.84	20	20	20	40
WLR-OSW-02	0	5	10	0	85	0.065	128	7.8	0.4	0	10	0	90

*Data reported for the 2016 survey as it was not recorded in 2014.
^Data reported for the first visit in 2015 as it was not recorded for the second visit (see Table 2 for sampling dates).

Table 6. Historical (H) and current (C) species records in the Grand River (G), Feeder Canal (FC) and Welland River and tributaries (W). Species at Risk are highlighted.

Scientific Name	HG	CG	FC	HW	CW
Actinonaias ligamentina	Y	Y	Y[SH]	N	N
Alasmidonta marginata	Y	Y	N	N	N
Alasmidonta viridis	Y	Y	N	N	N
Amblema plicata	Y	Y	Y[SH*]	N	N
Anodontoides ferussacianus	Y	Y	N	N	N
Amphinaias pustulosa	Y	Y	N	N	N
Elliptio complanata[1]	Y	N	N	N	N
Elliptio dilatata	Y	Y	N	Y[SH]	N
Epioblasma triquetra	Y[SH]	N	N	N	N
Fusconaia flava	Y	Y	N	N	N
Lampsilis cardium	Y[SH]	Y	N	N	N
Lampsilis fasciola	Y	Y	N	N	N
Lampsilis radiata[1]	Y[SH]	N	N	Y[SH]	N
Lampsilis siliquoidea	Y	Y	N	Y[SH]	Y
Lasmigona complanata	Y[2]	Y	N	N	N
Lasmigona compressa	Y	Y	N	N	Y
Lasmigona costata	Y	Y	Y[SH]	N	N
Leptodea fragilis	Y	Y	Y[SH]	Y[SH]	Y
Ligumia nasuta	Y[SH]	N	N	Y[SH]	Y
Ligumia recta	Y	Y	N	N	N
Obliquaria reflexa	Y[SH]	Y	N	N	N
Obovaria olivaria	Y[2]	N	N	N	N
Obovaria subrotunda	Y[SH]	N	N	Y[2]	N
Pleurobema sintoxia	Y[SH]	Y	N	N	N
Potamilus alatus	Y	Y	Y[SH]	Y[SH]	Y
Ptychobranchus fasciolaris	Y[SH]	Y[SH]	Y[SH]	Y[2]	N
Pyganodon grandis	Y	Y	Y[SH*]	Y[SH]	Y
Quadrula quadrula	Y	Y	Y[SH*]	Y[SH]	Y
Strophitus undulatus	Y	Y	N	Y[2]	Y
Toxolasma parvum	Y[SH]	Y	Y[SH*]	N	Y
Truncilla sp.	Y[SH]	Y	Y[SH*]	Y[SH]	Y
Utterbackia imbecillis	Y[SH]	Y	N	N	Y
Villosa iris	Y	Y	N	N	N
Live species richness	***19***	***26***	***0***	***0***	***11***
Total species richness	***31***	***27***	***10***	***11***	***11***
Overall species richness	***31***		***10***	***14***	

[1]These records are considered erroneous and are not included in the species richness.
.[2]Unknown from record whether animal was alive or a shell (not included in live species richness count).
[SH]Shells only.
*Shells also found by Schueler (2012).

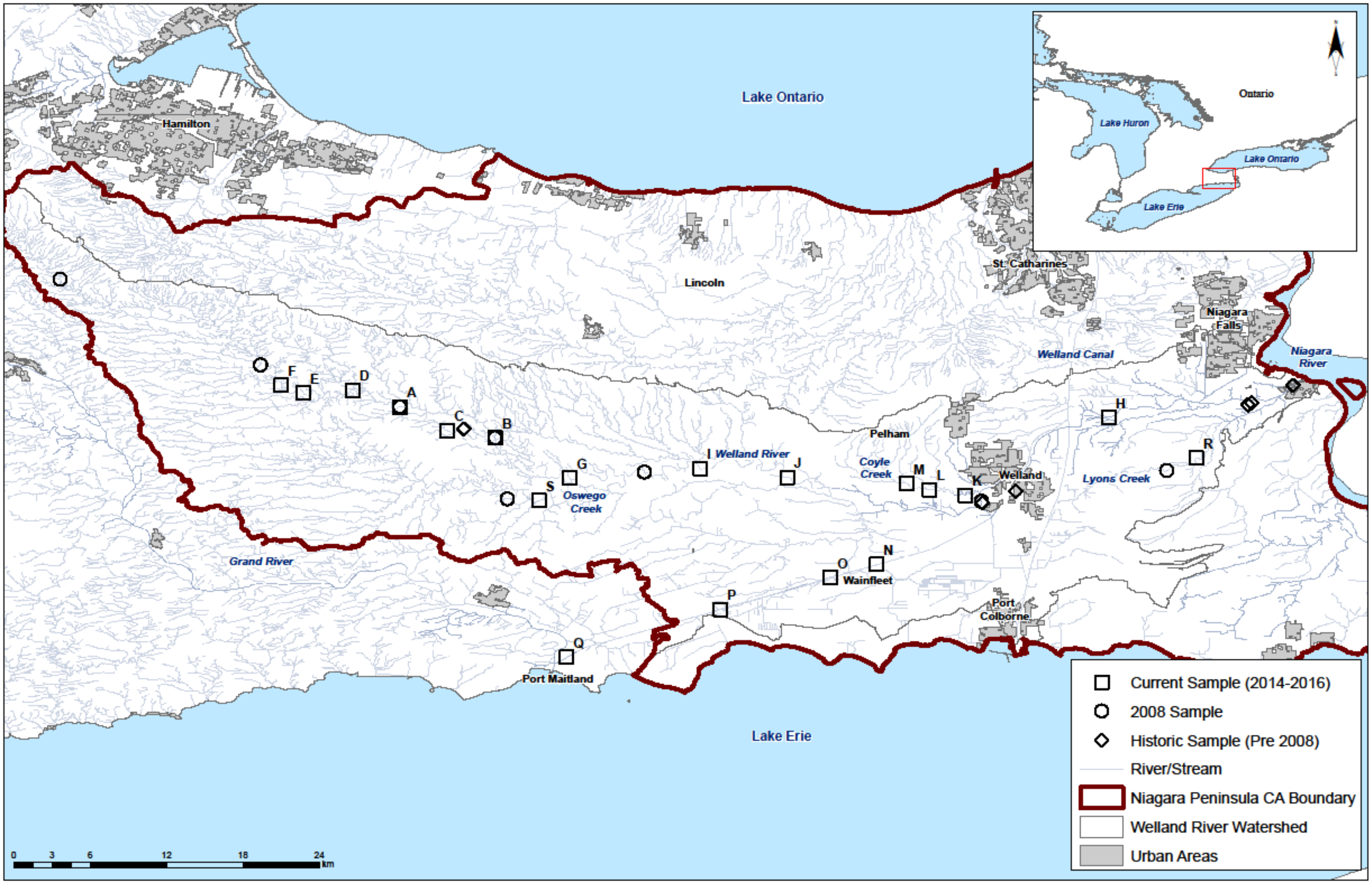

Figure 1. Historical, 2008, and current (2014-16) sites surveyed in the Welland River watershed. Current sites were sampled by Fisheries and Oceans Canada. Letters correspond to site codes in Table 2.

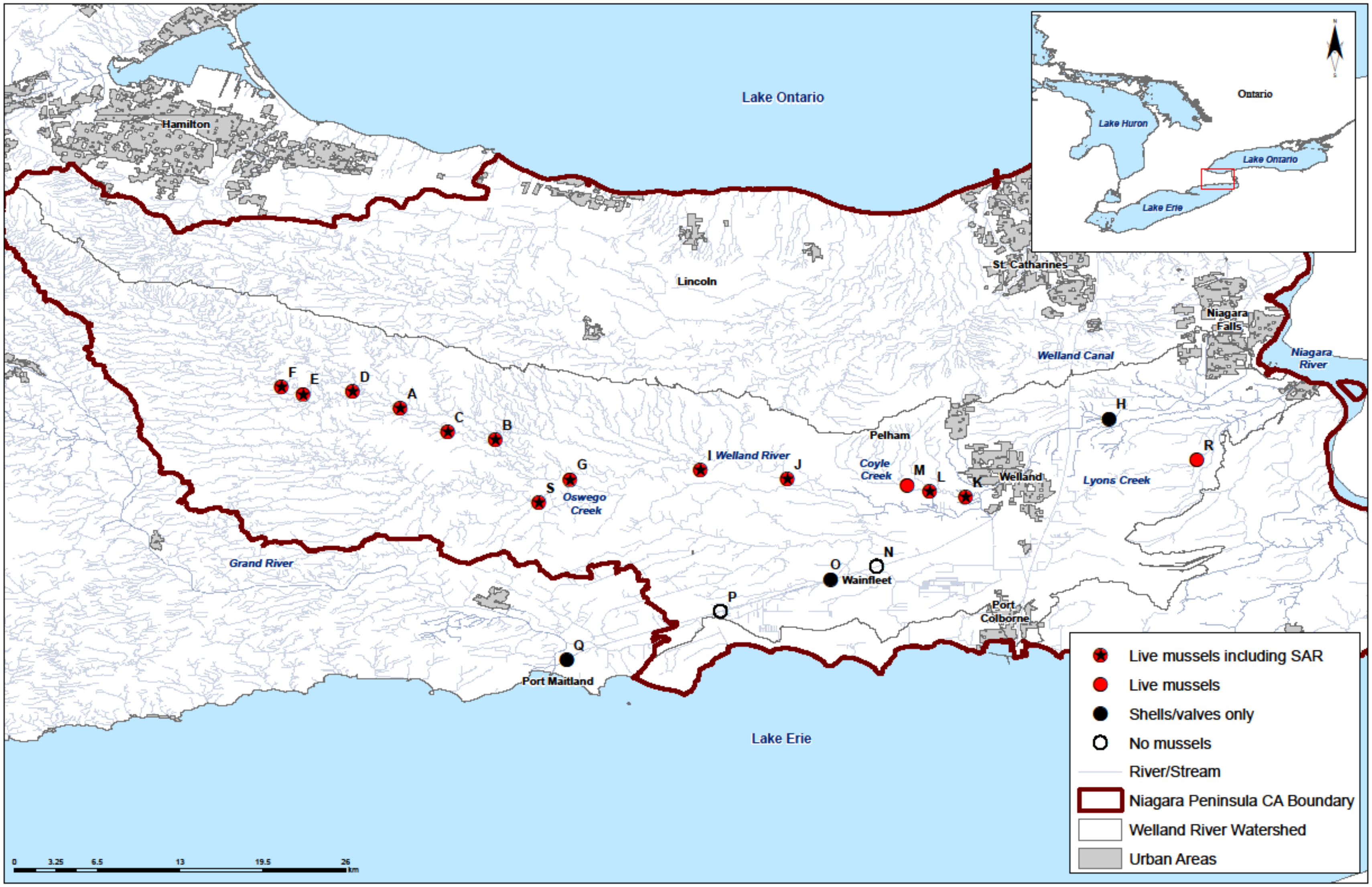

Figure 2. Presence and absence of mussels at sites sampled by Fisheries and Oceans Canada in 2014-16. Letters correspond to site codes in Table 2.

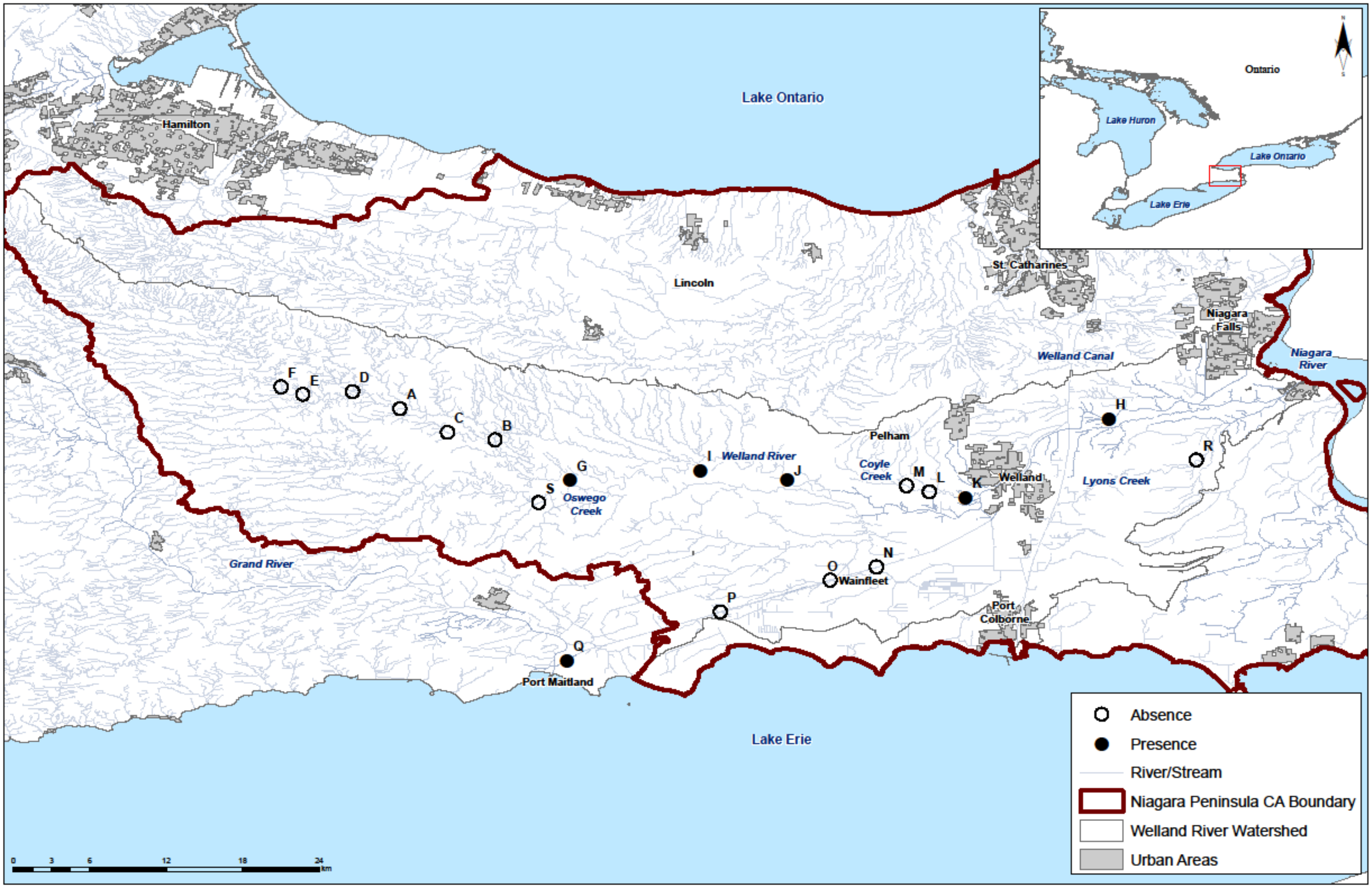

Figure 3. Presence and absence of Dreissena polymorpha *at sites sampled by Fisheries and Oceans Canada in 2014-16. Letters correspond to site codes in Table 2.*

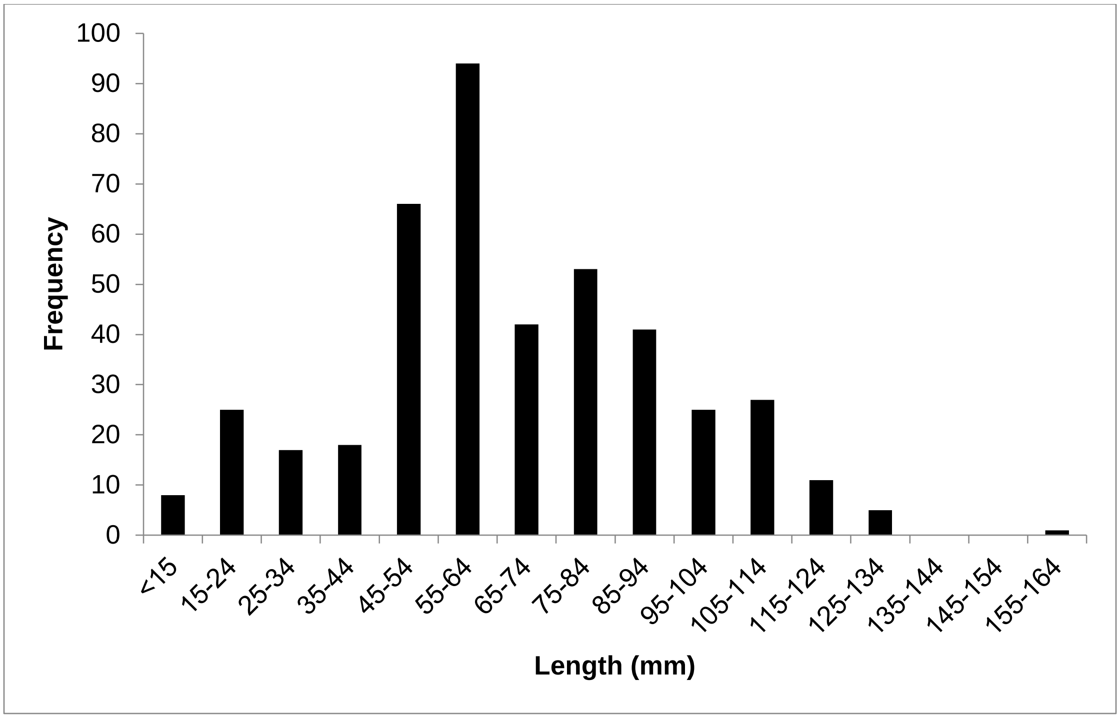

Figure 4. Length (mm) frequency distribution of Quadrula quadrula *measured in the Welland River watershed during 2014-16 surveys (n = 433).*

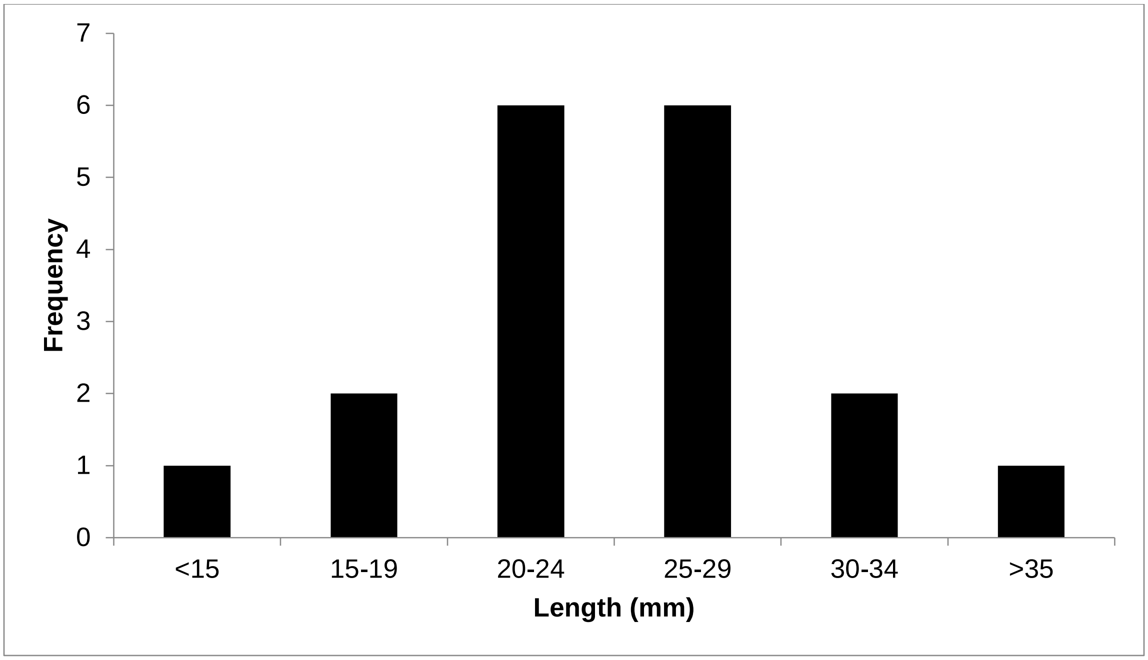

Figure 5. Length (mm) frequency distribution of Toxolasma parvum *observed in the Welland River watershed during 2014-16 surveys (n = 18).*

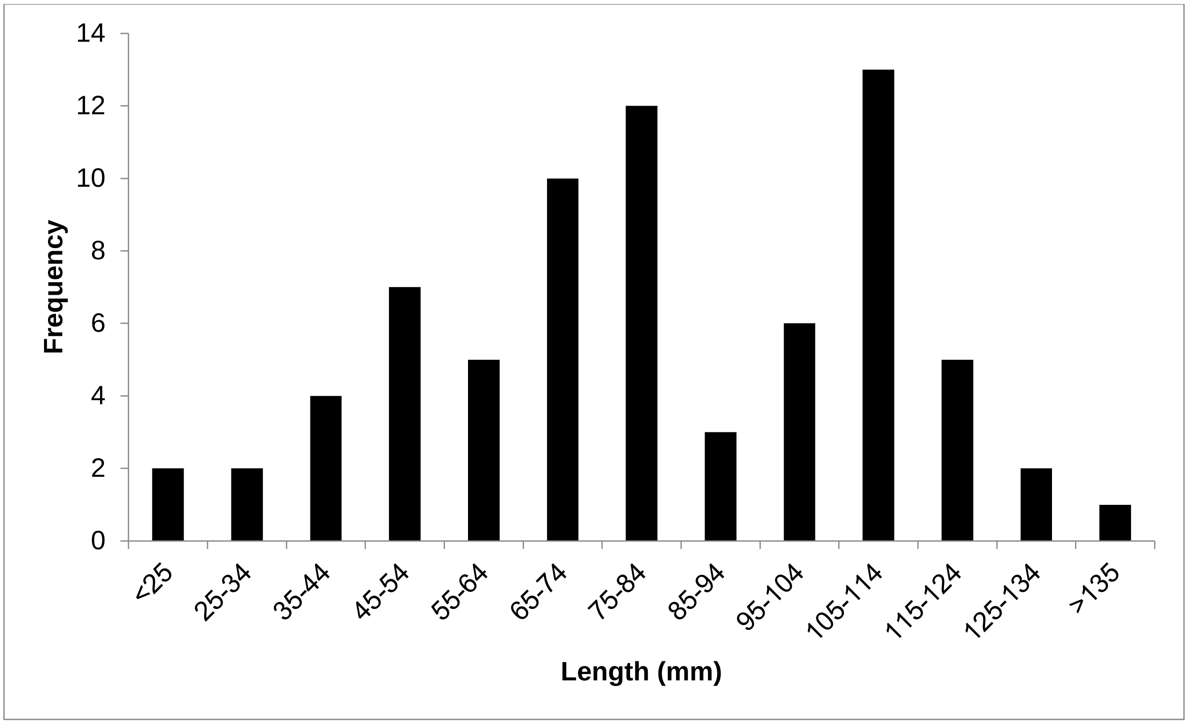

Figure 6. Length (mm) frequency distribution of Pyganodon grandis *observed in the Welland River watershed during 2014-16 surveys (n = 72).*

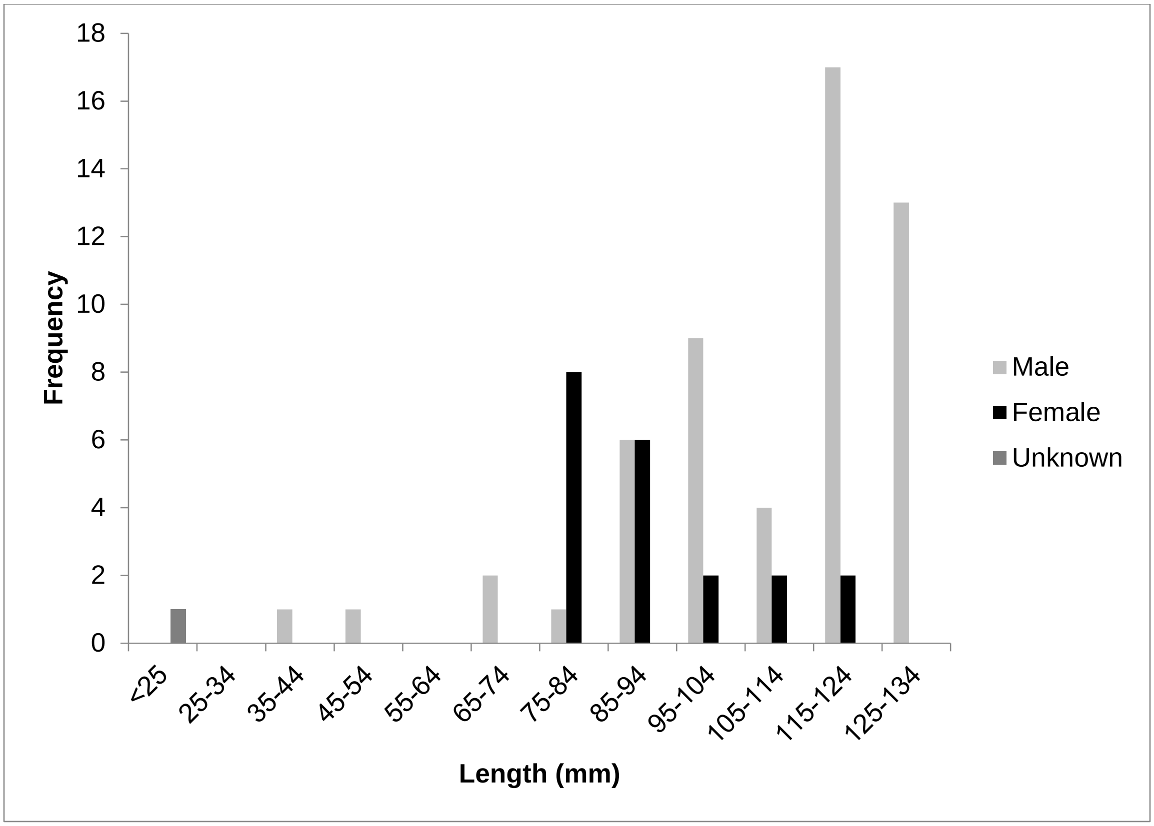

Figure 7. Length (mm) frequency distribution of male (n=54), female (n=20) and unknown (n=1) Lampsilis siliquoidea *observed in the Welland River watershed during 2014-16 surveys (n = 75).*

Figure 8. Site photograph of LON-FED-01 depicting the current state of stagnation and overgrowth which is consistent throughout the Feeder Canal.

Figure 9. Area where the majority of shells were found in Feeder Canal site WLR-FED-02 in 2015 (Photo credit: Brydon MacVeigh, Fisheries and Oceans Canada, 867 Lakeshore Rd., Burlington, Ontario, L7S 1A1).

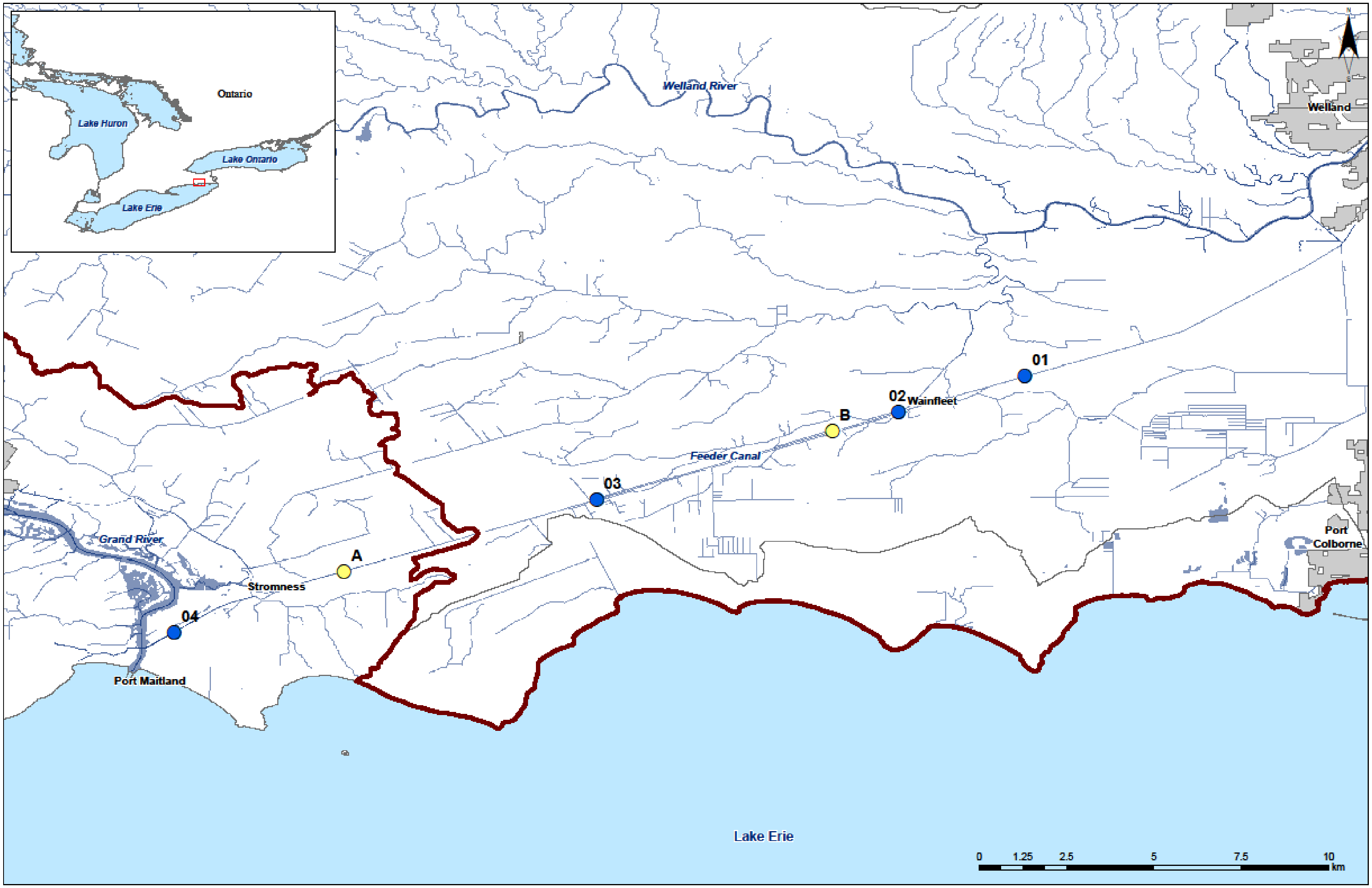

Figure 10. Locations of surveys in 2008 by Schueler (2012) (yellow; A = 42.88097, -79.52331W and B = 42.91726, -79.39770) and in 2015 by DFO (blue; 01 to 04=LON-FED-01 to 04, respectively). Red line indicates the Niagara Peninsula Conservation Authority boundary.