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The Crayfishes of Manitoulin Island

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ABSTRACT

The distribution of crayfish species found on Manitoulin Island in Lake Huron, Ontario, Canada was documented. Major water bodies on the island were surveyed in 2007, and again in 2012 and 2013. The island is geographically unique, as it is considered a refugium, similar geologically to regions located in more southern Ontario. Overall, fifty one sites were sampled on the main island, as well as smaller adjacent islands and the mainland. *Orconectes propinquus*, *Orconectes virlis* and *Cambarus bartonii* are the three native species found on the island. *Cambarus bartonii* was recorded at one site only, *O. virilis* occurred at twenty three localities, while *O. propinquus* was recorded at thirty two locations. The latter two species were in sympatry at fifteen of the locations. The introduced *Orconectes rusticus* occurred at eight localities, of which one was shared with *O. propinquus*. *Orconectes immunis*, *Cambarus robustus* and *Fallicambarus fodiens*, which occur in other parts of Ontario, were not found on the island. The significance of the overall distribution is discussed in terms of past surveys, as well as the present and future impacts of the introduced *O. rusticus* in model scenarios of existing and potential spread in southern Ontario and Quebec.

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INTRODUCTION

There are 11 species of crayfish found in Canada. Crayfish have now been recorded from all provinces except Newfoundland, North-West Territories, Yukon and Nunavut (Hamr 1998). Of all the provinces, Ontario has the richest fauna with nine confirmed species. The general distribution of crayfish in Ontario includes the entire Great Lakes basin, as well as the James Bay drainage. The range of habitats occupied by Ontario crayfish is quite wide and includes wetlands, wet meadows, stagnant water, ponds, ditches, reservoirs, lakes, intermittent, as well as permanent streams, and large rivers (Crocker and Barr 1968; Hamr 1998). The Great Lakes region of Ontario is an area of high aquatic biodiversity, which also includes the richest diversity of crayfish in Canada. *Orconectes rusticus* (Girard) is one of three species thought to have been introduced into southern Ontario from the United States in the early 1960s (Crocker and Barr 1968). The rusty crayfish has since spread throughout the province of Ontario and is now known to occur from Quebec in the east to Manitoba in the west (Hamr 2010). *Orconectes rusticus* was first found on Manitoulin Island in 2007 (present study), but the timing of its original introduction is not known, given the scarcity of available data.

Previous published records of crayfish on Manitoulin Island are limited and include only 4 localities in the Handbook of Crayfishes of Ontario (Crocker and Barr, 1968): *Orconectes virilis* (Hagen) and *O. propinquus* (Girard) from Manitou River and South Baymouth, collected in 1964. Given the vulnerability of terrestrial, as well as aquatic habitats on the island, it is important for future management to documents the distribution (historic and present) of all species native and introduced to the island.

Manitoulin Island is located in the northern part of Lake Huron and is the largest freshwater island in the world. The island has an area of 2,766 km^2 and separates the larger part of Lake Huron to its south and west from Georgian Bay to its east and the North Channel to the north (Figure 1). Although geographically considered part of Northern Ontario, the island is physiographically part of Southern Ontario, a region characterized by low relief and sedimentary

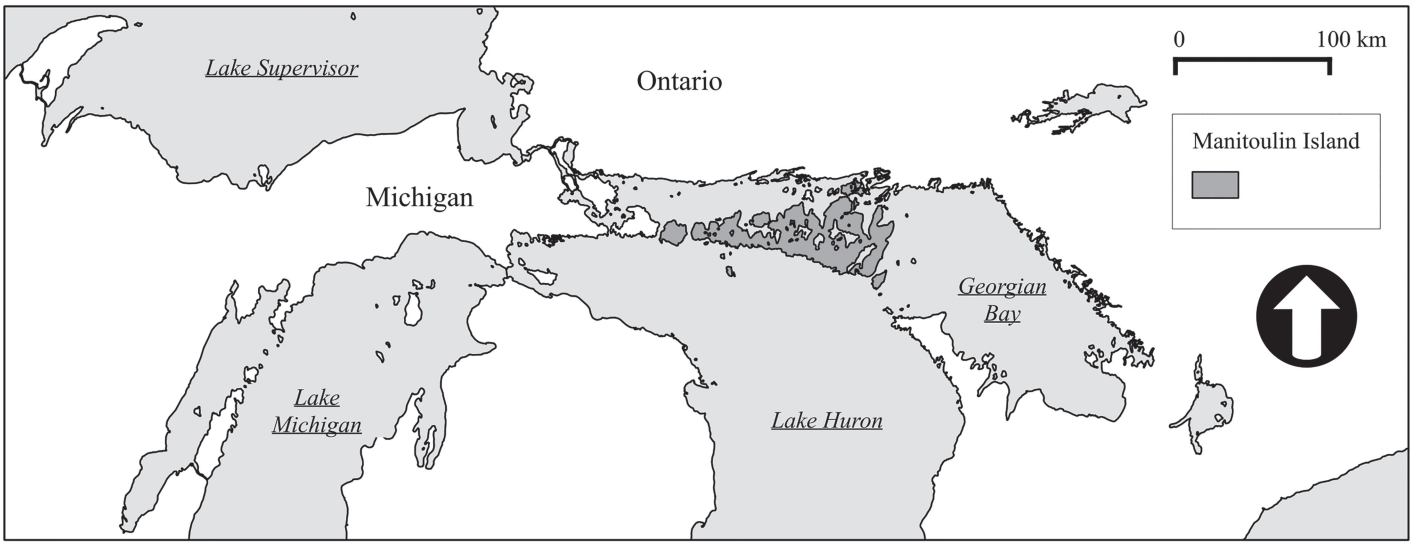

Figure 1. Location of Manitoulin Island (dark grey shading) within the Great Lakes of North America.

parent rock. Manitoulin Island contains 108 freshwater lakes. Lake Manitou, with an area of about 104 km^2, is the largest lake on a freshwater island in the world (Coniglio et al. 2006). Manitoulin Island also contains four major freshwater streams: the Kagawong, Mindemoya and Manitou Rivers, as well as Blue Jay Creek, all providing spawning habitat for rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta* Linnaeus) as well as several species of salmon (*Salmor salar* Linnaeus; *Oncorhynchus kisutch* (Walbaum)*, O. gorbuscha* (Walbaum)*; O. tshawytscha* (Walbaum)) (http://www.manitoulinislandfishing.com/manitou-river.html).

Manitoulin Island is underlain by Lorraine Quarzite, which originated from beach sand about 1.1 billion years ago. The island is an eastward extension of the Interior Plains, characterized by low relief and sedimentary bedrock, primarily dolomite. It is also a continuation of the Niagara Escarpment and Bruce Peninsula, a geological rock formation running south to Niagara Falls and continuing into New York State. Tan limestone (shale), which originated 490 million years ago, has also been found on Manitoulin and many of the smaller islands in Lake Huron (Coniglio et al. 2006).

The basins of all the present Great Lakes were sculpted by glaciations about 30,000 years ago. The last Ice Age ended 10,000 years ago, when the island took its present form and the first signs of aboriginal (Paleo-Indian) settlement on Manitoulin Island date back to this period. The removal of glacial ice weight caused the land to rebound slowly. The McGregor Bay area on Manitoulin Island is still rising at a rate of about 35 cm per century (Coniglio et al. 2006).

In addition to the original settlement and continued presence of First Nations, Manitoulin Island has experienced several waves of European immigration since the mid-1800s. The majority of European settlers have engaged in farming practices, however, the soils on the island offer only limited agricultural potential (pasture grasses, beef and dairy cattle, sheep). During the past three decades, off-shore cage aquaculture of salmonid species (rainbow trout - *Oncorhynchus mykiss* (Walbaum), and arctic char - *Salvelinus alpinus* (Linnaeus)) has been practiced at several locations on the island's periphery (http://www.manitoulinstreams.com/).

Of 51 large Manitoulin lakes investigated by Harvey and Coombs (1971) from 1965 to 1970, ten were dimictic and 41 shallow, polymictic. Twenty of the polymictic lakes have one or more trenches at the bottom. In Smoky Hollow (trenched) Lake, winter oxygen declined to less than 1 ppm before the spring thaw. Winter mortality of Yellow perch (*Perca flavescens* Mitchill) and Northern pike (*Esox lucius* Linnaeus) was observed in 3 lakes, but was deemed uncommon (Harvey and Coombs 1971). The survival of aquatic fauna in the many shallow lakes was made possible by the continued presence of a small amount of oxygen throughout winter and intrusions of surface melt-water under the ice sheet. Most of the Manitoulin Island lakes had a high pH (7.9 – 9.1) and were rich in magnesium (Mg mean 17.9 ppm) in relation to calcium (Ca mean 34.2 ppm), consistent with the underlying dolomitic bedrock. Sodium (Na mean 1.5 ppm) and potassium (K mean 0.8 ppm) were present at unusually low concentrations (Harvey and Coombs 1971).

Large areas of Manitoulin Island have been classified as "Facing High to Moderate Anthropogenic Disturbance" by the Ontario ministry of Natural Resources (Hagendorn and Timoshenko 2007). The Manitoulin Streams Improvement Association, formed in 2000, rehabilitates streams, rivers and creeks on Manitoulin Island with the goal of improving water quality and associated fisheries. They have conducted enhancement strategies and rehabilitated 17 major sites on Manitou River and 3 major sites on Blue Jay Creek. They have also completed work on Bass Lake Creek, Norton's Creek, and started working on the Mindemoya River in 2010 (http://www.manitoulinstreams.com/).

METHODS

Crayfish surveys were conducted during July 2007, July 2012 and in August 2013. The sampled sites were surveyed over a period of six days, three days in 2007 and again three days in 2012/13. All areas of the island were covered except for the

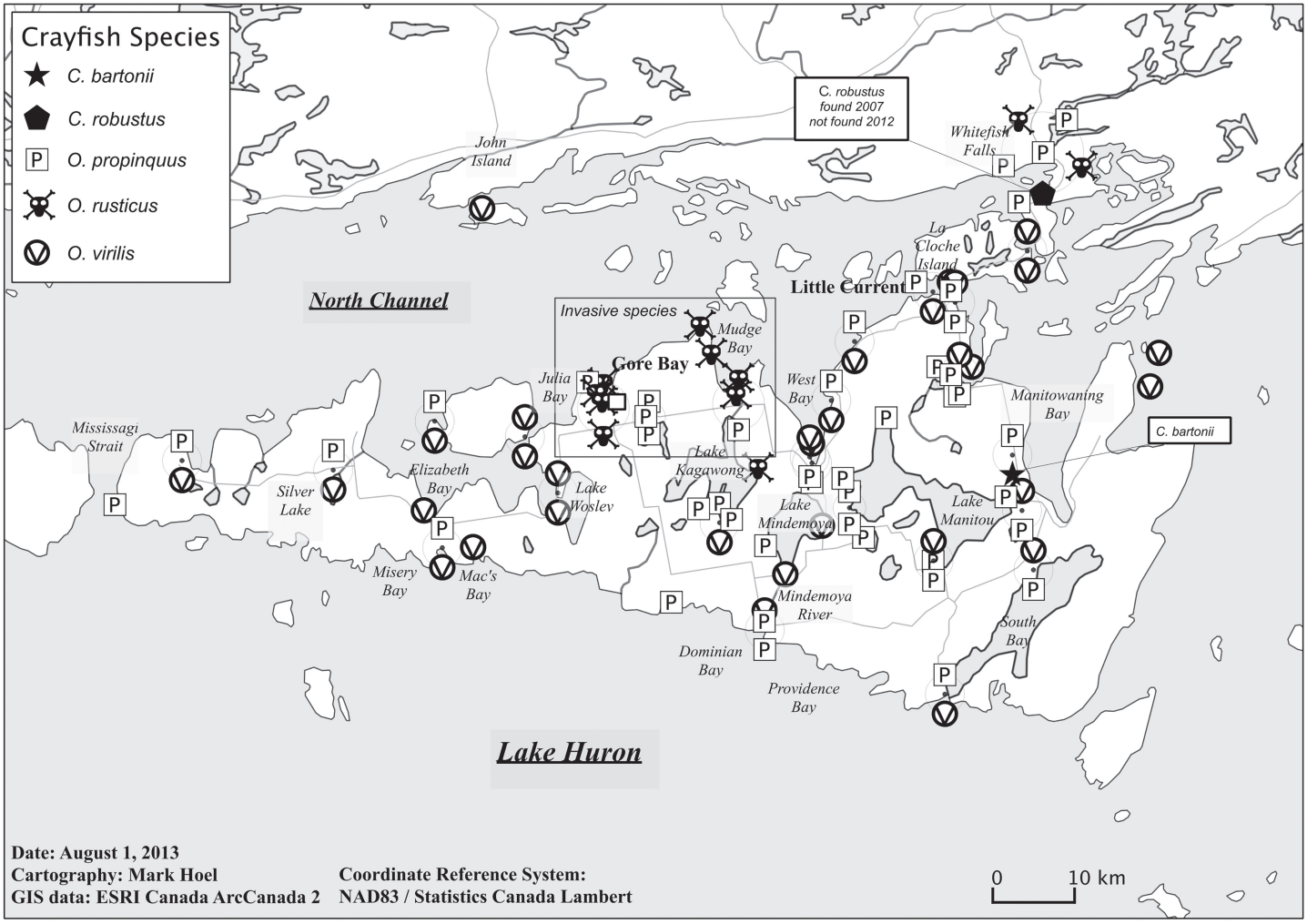

Figure 2. Distribution of crayfish species on Manitoulin Island, Georgian Bay, Ontario, Canada.

large Wikwemikong First Nation Territory in the east portion of the island, where access permits are necessary and could not be obtained in a timely manner. Samples were taken along shorelines by methodically searching all habitats at each site. The unit effort per site was kept constant (number of searchers, area searched and duration of search), ensuring that all crayfishes and habitats were sampled at each location. Crayfish were captured by hand or by dip nets. All individuals were identified, measured and checked for reproductive and moulting condition. Occurrence of each species was noted and the location was recorded using a Garmin Venture GPS unit. Water temperature and water chemistry measurements (pH, conductivity, total dissolved solids - TDS, and oxidation -reduction potential - ORP) were taken in 2012 by using a digital multimeter (Myron L Company). Data was processed and mapped using a GIS program developed by the Geography Department at Upper Canada College.

RESULTS

Overall, 51 sites were surveyed over the 3 years (2007, 2012 and 2013) and the surveys yielded 81 locality records for five different crayfish species in the region. On the island proper, three Orconectids and one Cambarid were found (Figure 2).*Cambarus bartonii* was the least abundant species and was recorded at only one site (Francis Brook, High Falls; E433711 N5072156). *Orconectes propinquus* was the most abundant species and was found at 32 sites (17 times it was the only species present); *Orconectes virilis* occurred at 23 sites (8 times it was the only species present). The two Orconectid species were observed in sympatry at 15 of the above sites.

The introduced *O. rusticus* was found at eight sites. This study was the first to record this invasive species (in the summer of 2007) on the island, but it is not clear how and when the species was introduced. Given the size and establishment level of several populations, it was probably introduced well prior to 2007, most likely by anglers as bait for game fish. *Orconectes rusticus* was observed in sympatry only with *O. propinquus* at 2 sites, suggesting that *O. rusticus* may be actively excluding the three native species. A large, well established, reproducing *O. rusticus* population was found at Bridal Veil Falls on the Kagawong River (E402576, N5083601), which connects Lake Huron's North Channel to Lake Kagawong. This population was comprised of multiple size classes, including young of the year and very large adults. *Orconectes rusticus* was also found in northern Lake Kagawong, (Mud Bay, E403591, N5075793) where they have presumably spread by migrating upstream from Bridal Veil Falls,

Table 1. The ranges of water chemistry and temperature collected during the 2012 and 2013 Manitoulin Island Surveys.

Water chemistry	North shore	Interior lakes	South shore
pH	6.9 – 9.0	7.9 – 8.6	8.6 – 8.8
Total dissolved solids (mS cm^{-1})	120 – 178	129 – 228	136 – 203
Conductivity (ppm)	183 – 350	271 – 890	210 – 310
Oxidation-Reduction Potential (mV)	78 – 160	81 – 157	54 – 62
Water Temperature (°C)	24 – 28	25 – 28	22 – 23

[Credit River 2012: pH 6.0 - 8.0; tds 439 - 577, Cond 640 - 816, ORP 132 - 199]

as well as downstream, where the Kagawong River runs into Mudge Bay (E402460, N5084781). *Orconectes rusticus* occured throughout Mudge Bay and westward along the North Channel in Gore Bay, but interestingly, not in West Bay to the east (Figure 2). To date, the *O. rusticus* invasion is limited to this area of the North Channel, as other northern localities had only *O. propinquus* and *O. virilis*. Similarly, only these two native species were found in Lake Mindemoya and Lake Manitou, as well as Lake Huron bays in the extreme east and west of the island. Along the South shore, comprised of alvars (areas of dry grassland growing on thin soils over a limestone substrate), only the two native Orconectids were found as well.

The water chemistry data collected in 2012 is shown in Table 1. The overall range of values for pH, conductivity, ORP and TDS were similar on the north and south shores, as well as in the interior lakes and streams. However, water temperatures appeared to be cooler on the south shore, which faces the open waters of Lake Huron. There does not seem to be a clear correlation between any water quality parameters and the distribution of the four crayfish species, but more data needs to be collected in order to establish any relationships.

On the mainland just north of the island, *C. robustus* was found at one site, Whitefish Falls (Figure 2) in 2007, but it was absent in 2012. This site was clearly taken over by *O. rusticus* since 2007, when *O. propinquus* and *C. robustus* were still abundant and only a few *O. rusticus* were found. In 2012, only very few *O. propinquus* remained, hybrids of *O. propinquus* and *O. rusticus* (crayfish with a mixture of external morphological features corresponding to both species) were found, and *O. rusticus* was very abundant. In the La Cloche Island group, just north of the island proper, *O. propinquus* and *O. virilis* were the only species observed (Figure 2).

DISCUSSION AND CONCLUSIONS

Only four of Ontario's nine crayfish species were present on Manitoulin Island. The two most common Ontario Orconectids, *O. propinquus* and *O. virilis* are the dominant species on the island and appear to be distributed throughout, from west to east, as well as south to north. They often occur in sympatry, as is the case in many southern Ontario water bodies, and have been shown to have similar habitat requirements. Only one Cambarid species, *C. bartonii,* was found at only one location, at High Falls on the east coast of the island, where it had been previously recorded in 1985 (Schueler, pers. com.). This species prefers cool, fast water (waterfalls and rapids), high in dissolved oxygen (Hamr and Berrill 1985), and thus may be absent from the other water bodies and shores of the island, which do not provide the appropriate conditions for its survival. It is quite likely that *O. rusticus* gradually excluded *C. bartonii* from Bridal Veil Falls, which is the Cambarid's typical habitat, but unfortunately, no previous records from that locality exist. The absence of *C. robustus* on the island proper is somewhat unexpected, as the species is common in the rivers draining into Georgian Bay, as well as those of southern Ontario in general. It is not clear whether this species is altogether absent, as several areas of the island were not fully surveyed, but since no previous records exist, it's absence may again be a function of its habitat preference for swift flowing water (Crocker and Barr 1968; Hamr and Berrill 1985) which is generally rare on Mantoulin Island. The introduced *O. rusticus* is present and expanding, but perhaps not as fast as expected over the last 5 years. However, Manitoulin Island water bodies could eventually be overtaken by *O. rusticus*. Continued monitoring would offer a chance to study the invasive species' temporal and spatial expansion, as well as the impact on native crayfish species. The absence of the three burrowing species (*Fallicambarus fodiens* (Cottle), *Cambarus diogenes* Girard and *Orconectes immunis* Hagen), present in southern Ontario, is probably due to a combination of colder winter temperatures on Manitoulin Island and the absence of wetlands with clay soil.

The only previously published records of crayfish on Manitoulin Island are those cited in Crocker and Barr's (1968) book, in which the authors reported *O. virilis* and *O. propinquus* from only four localities (in the Manitou River and at South Baymouth), which were confirmed by the present study. Crocker and Barr (1968) did not report either *C. bartonii* or the introduced *O. rusticus*. More recent, but unpublished records collected by Dr. Frederick Schueler and Aleta Karstad of the Bishops Mills Natural History Center between 1984 and 2008, included six new localities for *O. virilis,* twelve for *O. propinquus,* and one for *C. bartonii.* Although *O. rusticus* was not found in their surveys, the distribution of the other three species at these localities corresponded to the data collected in this study.

Manitoulin Island may represent a good small scale model for studying the effects of *O. rusticus* in Southern Ontario. Future research should concentrate on completing surveys in the various First Nations Territories on the Island, as well as adjacent

Cockburn Island; monitoring the *O. rusticus* expansion along North Channel and in Lake Kagawong; and educating the local population, tourists, and anglers, to prevent further expansion of *O. rusticus* by accidental translocations. The *O. rusticus* at these sites appear to be well established and reproducing and therefore, it would be extremely difficult to eliminate the species from the island. However, close monitoring and elimination of any recently translocated populations in the future will be crucial in preventing a takeover by *O. rusticus* of the native crayfish populations on the island. This is particularly important as both *O. propinquus* and *O. virilis* have been shown to be particularly vulnerable to extirpation via competitive exclusion by *O. rusticus* (Momot 1992; DiDonato and Lodge 1993; Hamr 2010). Additionally, the vast majority (over 95%) of the crayfish distribution points overlap with the areas classified as "facing high to moderate anthropogenic disturbance" by the Ontario Ministry of Natural Resources (Hagendorn and Timoshenko 2007), and thus the native crayfish populations on the island are under threat not only from the spread of introduced species, but also from identified anthropogenic stressors, such as habitat alteration and pollution. The results of this study can therefore be used to implement future management strategies, as well as the assessment of future impacts caused by the above-mentioned stressors.

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LITTERATURE CITED

CONIGLIO M, KARROW P AND RUSSELL P (2006). Manitoulin Rocks!: Rocks, Fossils and Landforms of Manitoulin Island. University of Waterloo Earth Sciences Museum; 1st edition.

CROCKER D AND BARR D (1968). Handbook of the Crayfishes of Ontario. Toronto. University of Toronto Press.

DIDONATO GT. AND LODGE, DM (1993). Species replacement among *Orconectes* crayfish in Wisconsin lakes: Role of fish predation. *Canadian Journal of Fisheries and Aquatic Sciences* 50:1484–1488.

HAGERDORN D AND TIMOSHENKO N (2007). Identifying and prioritizing land suitable for alvar conservation initiatives on Manitoulin island using GIS. University of Guleph. Geography Department. http://www.uoguelph.ca/geography/research/geog4480_w2007/Group04/index.html

HAMR P (1998). Conservation status of Canadian freshwater crayfishes. Report for the World Wildlife Fund Canada. WWF Canada. Toronto, Canada.

HAMR P (2010). The biology, distribution and management of the introduced rusty crayfish *Orconectes rusticus* (Girard) in Ontario, Canada. *Freshwater Crayfish* 17:85–90.

HAMR P AND BERRILL M (1985). The life histories of north-temperate populations of the crayfish *Cambarus robustus* and *Cambarus bartoni*. *Canadian Journal of Zoology* 63:2313–2322.

HARVEY HH AND COOMBS JF (1971). Physical and chemical limnology of the lakes of Manitoulin Island. *Journal of the Fisheries Research Board of Canada* 28:1883–1897.

MANITOULIN ISLAND FISHING ONTARIO CANADA (2007). Homepage. http://www.manitoulinislandfishing.com.

MANITOULIN STREAMS IMPROVEMENT ASSOCIATION (2013). HOMEPAGE. http://www.manitoulinstreams.com

MOMOT W (1992). Further range extensions of the crayfish *Orconectes rusticus* in the lake Superior basin of northwestern Ontario. *Canadian Field Naturalist* 106:397–399.

SUPPORTING INFORMATION

The following supporting information is available for this article:

Appendix S1. Sampling localities for the crayfish specimens collected from Manitoulin Island during the course of this study. [*AppendixS1_Manitoulin_Crayfish_Localities.xlsx*].

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