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Rapid Communication

First record of the invasive Asian earthworm *Amynthas tokioensis* (Beddard, 1892) in the province of Québec, Canada

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Abstract

The presence of non-native Asian earthworms in northeastern North America has raised concerns in the last decades following the observation of how intensely they can disturb the soil and initiate cascading effects in invaded areas. A recent study showed that the known northern distribution of these earthworms in northeastern North America reached the southern parts of the province of Ontario (Canada) as well as the northeastern states in the U.S.A. that border the province of Québec (Canada). In 2021, more specimens were found in southern Ontario and in the province of New Brunswick. Here we report the first record of a non-native Asian earthworm (*Amynthas tokioensis)* in the province of Québec, which confirms the progression of the invasive Asian earthworms in Canada.

Key words: non-native species, invasive species, Asian earthworms, jumping worm

Introduction

Non-native European earthworms are well established in northeastern North America and can be found as far north as the Canadian boreal forests and taiga (Moore et al. 2022). Although their effects are usually viewed as beneficial for agriculture, the situation is quite different for forest ecosystems. The main environmental issues reported after their invasion are mainly linked to the alteration of the forest floor, which affects the distribution of carbon, nitrogen and other chemicals, roots, microbes and other components of the soil fauna, and even understory vegetation (Addison 2009; Drouin et al. 2016; Moore et al. 2018; Lejoly et al. 2023).

Additional concerns about forest ecosystems in northeastern North America emerged in the last decades with the invasion of non-native Asian earthworms (or so-called jumping worms) in several areas (Hale 2008; Görres and Melnichuk 2012; Reynolds 2014; Puhlick et al. 2021; Reynolds and McTavish 2021; McAlpine et al. 2022). Although the worms in this region have generally an annual life cycle (Chang et al. 2021), their rapid growth and intense activity cause them to upset both the soil and the ecosystem very quickly.

Figure 1. Urban perennial flowerbed in the city of Saint-Jérôme (region of Montréal, Québec, Canada) in which adult *Amynthas tokioensis* were first reported in September 2022, followed by aclitellate adults in June 2023. Photo by J.-D. Moore.

Moore et al. (2018) reviewed the vulnerability of southeastern Canada to colonization by Asian earthworms and the negative effects that these organisms were likely to have on forest ecosystems. Although at the time the only mention of their presence in the country was in Ontario (Reynolds 2014), Moore et al. (2018) concluded that "although regulations and awareness may delay their expansion, Asian earthworms are likely to spread further north into Canada". Recently, Asian earthworms were reported in New Brunswick (McAlpine et al. 2022), and more occurrences were documented in southern Ontario (Reynolds and McTavish 2021). Here we report the first record of a non-native Asian earthworm species in the province of Québec, Canada.

Materials and methods

The Asian earthworm population reported here was first noticed in September 2022 by Tristan Tamilia, an employee of the city of Saint-Jérôme, north of Montréal (Québec, Canada; lat. 45.776646°N; long. −73.999929°W). The invaded area, owned by the city, was an urban perennial flowerbed (Figure 1). In June 2023, JDM revisited the original flowerbed as well as others nearby (within approximately 50 m; Figure 2). Jumping worms were found under a layer of wood mulch at the two sites where they were present in Fall 2022. Comparatively to the observation made in the fall of 2022 (Figure 3), wood mulch had not yet been incorporated, and no aggregates from earthworm droppings were found (Figure 4). JDM's visit was intended to confirm the presence of exotic Asian earthworms at this site and others nearby—not to make an inventory of all the species of earthworms present, nor to measure their density.

Earthworm specimens were identified by JWR based on internal and external morphology as well as on the keys and diagnoses provided by Reynolds (1977, 2022, 2023) and Chang et al. (2016).

Figure 2. Urban landscaped border in the city of Saint-Jérôme (region of Montréal, Québec, Canada) where the aclitellate adult *Amynthas tokioensis* specimen was reported in June 2023. Photo by J.-D. Moore.

Figure 3. Jumping worm aggregates mixed with wood mulch at the original site in September 2022 (city of Saint-Jérôme, region of Montréal, Québec, Canada). Photo by T. Tamilia.

Results and discussion

Presence of Asian earthworms in Québec, and their capacity to survive in Canada

We found in this area of the province of Québec (Canada; Figure 5) a total of 13 aclitellate *Amynthas tokioensis* (Beddard, 1892) (syn. *Metaphire levis*)

Figure 4. Substrate at the original site in June 2023 (city of Saint-Jérôme, region of Montréal, Québec, Canada). Photo by J.-D. Moore.

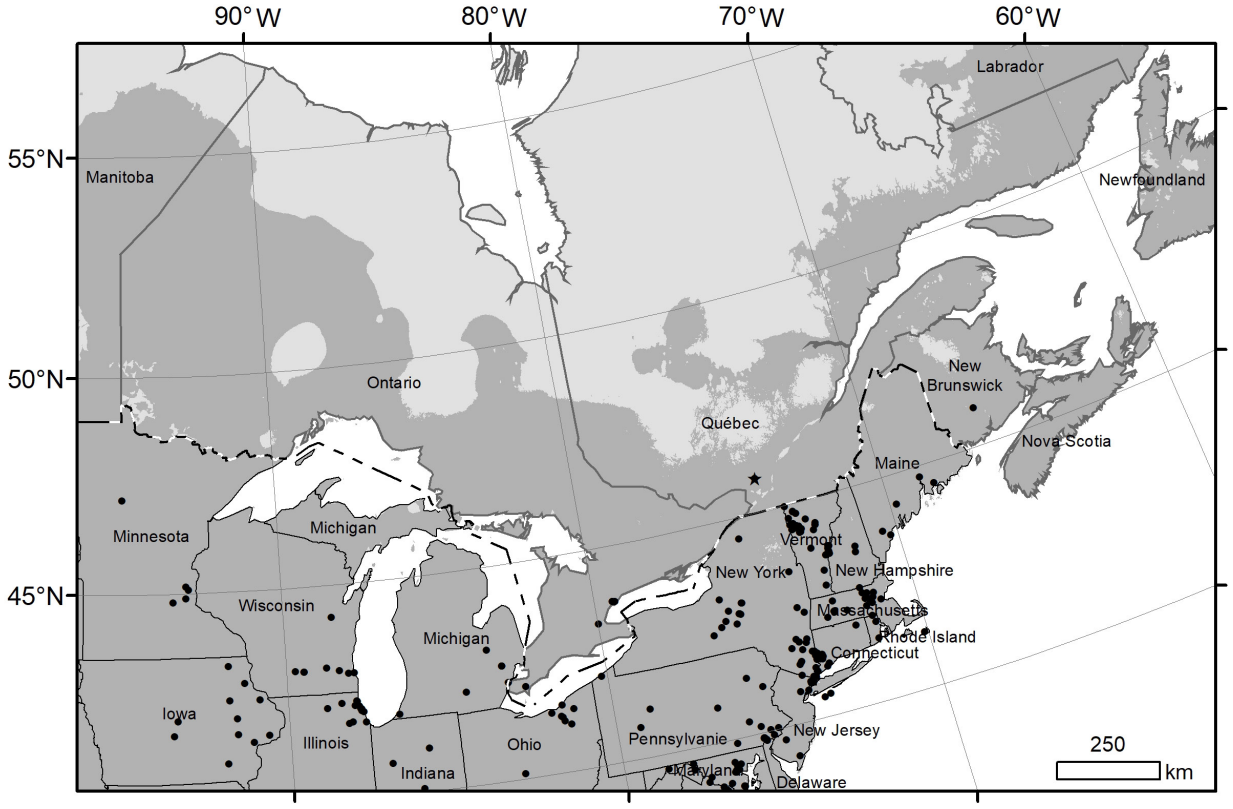

Figure 5. Distribution map of non-native Asian pheretimoid earthworms (*Amynthas* spp., *Metaphire* spp.) in northeastern North America (n = 258 sites), modified from Moore et al. (2018). Potential "invadable" zones (where there are ≥ 90 frost-free days) appear in dark gray. Frost-free days were estimated using BioSIM software (version 10.2.5.39, 2013) from climatic normals (1981–2010). Ontario occurrences are from Reynolds (2014) and Reynolds and McTavish (2021), and New Brunswick occurrences are from McAlpine et al. (2022). The new Québec occurrence is indicated with a star.

Figure 6. Aclitellate adult of *Amynthas tokioensis* observed in June 2023 in an urban landscaped flowerbed in Saint-Jérôme (Montréal region, Québec, Canada). Photo by J.-D. Moore.

Figure 7. Adult jumping worm (probably *Amynthas tokioensis)* observed in September 2022 in an urban perennial flowerbed (city of Saint-Jérôme, region of Montréal, Québec, Canada). Photo by T. Tamilia.

adults, approximately 2.5 inches (6.5 cm) in length, at the original site (Figure 6), and one at another site 50 m away. By comparison, the first adult specimens that had been observed by the city worker in the fall of 2022 were approximately 5 inches (13 cm) long (Figure 7). All specimens found in 2023 were quadrithecal, with developed testes and ovaries, which is why they were recorded as aclitellate adults rather than as juveniles. Pre-clitellar genital markings small, circular discs, paired in front of the setal line on vii and viii, median to the spermathecal pores, some specimens with an additional disc right in front of the pore on vi and/or vii.

The first occurrences of jumping worms in Canada were documented in 2014 in Ontario (Reynolds 2014). Others were recorded in 2021 in several other areas in Ontario (Reynolds and McTavish 2021) as well as in New Brunswick

(McAlpine et al. 2022). Recent collections indicate that jumping worms are also found in Nova Scotia and Prince Edward Island, probably as a result of horticultural activities (J.W. Reynolds *unpublished data*). *Amynthas tokioensis* was the dominant species in Saint-Jérôme (Québec), as was the case in New Brunswick, but not in Ontario. The observations of Asian earthworms in Canada are not entirely a surprise, as Moore et al. (2018) reported that they were already observed in many states in the U.S.A. that border Canada, including *Metaphire* species and other *Amynthas* species (Figure 5). Given that Asian earthworm populations established in the U.S.A. were sometimes found in areas where temperatures are colder than what is observed in some Canadian provinces, Moore et al. (2018) had predicted that these species would eventually colonize other areas in Canada with a similar or better climate, if they had not done so already. Recent observations of Asian earthworms in Ontario, Québec, New Brunswick, Nova Scotia and Prince Edward Island support this hypothesis. All the observations made in the five Canadian provinces are in the potential "invadable" zones defined by Moore et al. (2018) based on the presence of ≥ 90 frost-free days (Figure 5).

Origin of Asian earthworms in northeastern North America and Saint-Jérôme

The origin of Asian earthworm occurrences in Saint-Jérôme is unknown. Compost operations, horticulture, and fishing may be vectors by which these organisms are spread (Görres and Melnichuk 2012). In the studied area of Québec, horticulture and wood mulch could have been implicated.

Presence and possible impacts of Asian earthworms in forest ecosystems

Over the last few decades, apprehension has grown about the introduction and spread of Asian earthworms into new territories, because their biological traits are compatible with a greater potential for colonization and disturbance than some European species. Yet, most of the invaded areas reported in Canada are non-forested, but Asian earthworms have invaded forest ecosystems in the neighbouring northeastern states in the U.S.A. over the last decades (Görres and Melnichuk 2012), and most recently in Ontario (Reynolds and McTavish 2021). This suggests that their invasion of forest ecosystems in Canada is just a matter of time, if not already a reality.

Although Asian earthworm invasions are a relatively new phenomenon in northeastern North America, concerns about their effects on the soil ecosystem have prompted numerous studies in the last decades. Literature reviews on this topic were published recently (Moore et al. 2018; Chang et al. 2021). In general, jumping worms generate rapid and considerable depletion of the forest floor (Zhang et al. 2010; Greiner et al. 2012; Moore et al. 2013; Qiu and Turner 2017) and induce changes in soil structure (Snyder et al. 2011; Greiner et al. 2012; Chang et al. 2016). Coupled with a rapid mineralization of

nutrients (Burtelow et al. 1998; Steinberg et al. 1997; Greiner et al. 2012; Qiu and Turner 2017), this may render forest ecosystems more susceptible to nutrient losses. All these changes may lead to cascading effects on vegetation and soil biota (McLean et al. 2006; Qiu and Turner 2017).

Conclusion

This addition to the recent published observations in Ontario, New Brunswick, and unpublished ones in New Scotia and the Prince Edward Island means that five provinces in eastern Canada are now known to be colonized by these invasive Asian earthworms. Although regulations and awareness may delay their expansion, Asian earthworms are likely to spread further throughout Canada, and are expected to cause important changes to the biodiversity and dynamics of the newly invaded ecosystems.

Authors' contribution

Earthworm collection, interpretation of results and initial writing and editing of this manuscript were done by JDM. JWR identified species. JWR also wrote and edited the manuscript. All authors have read and agreed to the published version of the manuscript.

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