Interceptions and captures of *Halyomorpha halys* (Hemiptera: Pentatomidae) in Quebec from 2008 to 2018

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The brown marmorated stink bug, *Halyomorpha halys* (Heteroptera: Pentatomidae), was monitored in southern Quebec through a network of 137 baited pyramid traps deployed in urban and rural habitats between 2014 and 2017. Overall, 73 adults and 9 nymphs were captured. The first capture in rural (an apple orchard) and in urban areas (in Montreal) were observed in 2016. In that same year, 87% of the 54 individuals (adults) caught in Montreal were from a single trap. Similarly in 2017, only two adults were captured in rural habitats and 87% of the 25 captures (16 adults and 9 nymphs) in urban habitats were from the same trap as in 2016. This trap was the only one in which nymphs of various stages were collected, which suggests population establishment in Montreal. Haplotyped specimens from this site (four adults and two nymphs) were all of the H1 haplotype. Over 40 interceptions and sightings by citizens during the period 2008-2018 are also reported.

Keywords: brown marmorated stink bug, Canada, monitoring, invasive species.

[Interceptions et captures de *Halyormorpha halys* (Hemiptera: Pentatomidae) au Québec de 2008 à 2018]

La punaise marbrée, *Halyomorpha halys* (Heteroptera: Pentatomidae), a été dépistée dans le sud du Québec à travers un réseau de 137 pièges pyramidaux appâtés déployés en milieux urbains et ruraux entre 2014 et 2017. Au total, 73 adultes et 9 nymphes ont été capturés. La première capture en milieu rural (un verger de pommiers) et les premières captures en milieu urbain (à Montréal) ont été rapportées en 2016. La même année, 87 % des 54 individus (adultes) capturés à Montréal provenaient du même piège. Similairement en 2017, seulement deux adultes ont été capturés en milieu rural et 87 % des 25 captures (16 adultes et 9 larves) en milieu urbain ont été observées dans le même piège qu'en 2016. Ce piège a aussi été le seul dans lequel des larves de différents stades ont été capturées, suggérant un établissement de population à Montréal. Les spécimens de ce site (quatre adultes et deux larves), séquencés à cette fin, se sont révélés être de l'haplotype H1. Plus de 40 observations et interceptions par les citoyens entre 2008 et 2018 sont aussi rapportées.

Mots clés : punaise marbrée, Canada, dépistage, espèce envahissante.

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The brown marmorated stink bug *Halyomorpha halys* (Stål) (Heteroptera: Pentatomidae) (BMSB) is a polyphagous insect native to Asia that is quickly spreading and threatening crops in various countries of its introduced range. Lee *et al.* (2013) reviewed the biology, ecology and management of BMSB in its native range of China, Japan, and South Korea, and Leskey and Neilsen (2018) did the same for its introduced range of North America and Europe.

The worldwide range expansion of BMSB has been described by Haye *et al.* (2015). It can be summarized as the rapid spread of an invasive species which is still in expansion in all continents (except Antartica), as updated in EPPO Global Database (2018). Following its introduction in Pennsylvania (USA) in 1996 (Hoebeke and Carter 2003), BMSB has been found in 44 states as of today (StopBMSB 2018), which means in all states except Alaska, Wyoming, Montana, Oklahoma, South Dakota and Louisiana. In Canada, the first established populations of BMSB have been found in Ontario in 2012, two years following its first detection in the country (Gariepy *et al.* 2014). Abram *et al.* (2017) also reported an established population in 2016 in British Columbia, but except for Quebec, to our knowledge no other Canadian provinces have reported any occurrence of the bug. The first scientific paper reporting the BMSB in Quebec was based on one adult specimen (deposited in the Canadian National Collection) collected near a skid from USA in Montreal in 2010 (Fogain and Graff 2011). In the present scientific note, we aim to document interceptions that were hitherto unpublished or reported partially in Légaré *et al.* (2014). We also report on captures gathered by monitoring networks deployed in rural and urban habitats of southern Quebec from 2014 to 2017.

Interceptions and sightings

The first authenticated mention of BMSB in Quebec is an adult collected on February 15, 2008, from imported material (vegetable juice) (Légaré *et al.* 2014). The first authenticated mention of a specimen from the wild is an adult caught in June 2014 on a white sticky trap installed in an apple orchard of Hinchinbrooke (45°01′18.0″N 73°59′19.8″W) and sent to the Hudson Valley Lab for identification (Jentsch, personal communication). The first authenticated mention of a living specimen is an adult collected in the city of Laval (45°36′14.2″N 73°43′03.5″W) from a group of similar pentatomids sheltered in a motor home in November 2014, and first nymphs were identified in 2016 from a plant bought in a Montreal hardware store (45°31′42.7″N 73°36′32.0″W; reported with fewer details by Légaré *et al.* 2014). Several specimens reported by Montreal citizens were also authenticated in 2016 (21 adults), 2017 (12 adults and 3 nymphs) and 2018 (21 adults) from five different boroughs: Plateau-Mont-Royal (a total of 42 adults and 3 nymphs from nine sites); Outremont (a total of six adults from three sites); Ville-Marie (a total of three adults from one site); Côte-des-Neiges–Notre-Dame-de-Grâce (a total of two adults from two sites); Le Sud-Ouest (one adult). Coordinates of each borough, in citation order: 45°31′18″N 73°34′32″W; 45°31′00″N 73°37′00″W; 45°30′31″N 73°33′46″W; 45.47617°N 73.62705°W; 45°27′21″N 73°35′33″W.

Monitoring network

Following the first mention of BMSB in the outdoors, a network of baited pyramidal traps (described by Leskey *et al.* 2012) was established in 2014 by the Quebec ministry of agriculture (ministère de l'Agriculture, des Pêcheries et de l'Alimentation [MAPAQ]) in agricultural areas scattered along the southern border of the province. In 2015, a second network was established by the Canadian ministry of agriculture (Agriculture and Agri-Food Canada [AAFC]) in various rural (agricultural and natural) habitats of the province, and in 2016, a third network was established in the urban habitat of Montreal. The three networks operated independently each year but were coordinated by our team and used similar traps and baits. The global network comprised 30 traps in 2014 (27 in rural habitats and three in urban habitats), 74 in 2015 (70 in rural habitats and 4 in urban habitats), 90 traps in 2016 (78 in rural habitats and 12 in urban habitats) and 120 in 2017 (94 in rural habitats and 26 in urban habitats). Rural habitats (in which 80% of traps were deployed overall) comprised agricultural commodities (sweet corn, apples, soybeans, ornamentals), nurseries, campgrounds, airports, golf courses, packing houses, rest areas, natural parks; urban habitats comprised residential, industrial and vacant lots, cemeteries and city parks. The traps consisted of two 5 mm thick black corrugated triangular plastic panels (width: 30 cm, height: 109 cm) covered with black screening (mesh size: 2 mm x 2 mm), imbricated perpendicularly and topped with an inverted plastic collection jar (height: 16 cm, width: 10 cm) and a funnel (internal cone opening: 1.6 cm) inserted at the bottom. Each jar was modified by adding screened ventilation holes (diam.: 3 cm) on the sides and the bait was hung inside the jar, along with a 2 cm x 5 cm insecticide strip (Ortho Home Defense, dichlorvos 19%, registration #22027). The bait contained the two following lures: a) the *H. halys* aggregation pheromone (Khrimian *et al.* 2014) and b) 66 mg of methyl (E,E,Z)-2,4,6-decatrienoate (MDT) synergist (Weber *et al.* 2014). It was formulated into a rubber septa (for the pheromone) and a sachet (for the synergist) in the first year and in one single sachet the following years. Traps and lures were from AgBio (Westminster, CO) except in 2014, when the pheromone was obtained from the USDA (ARS Kearneysville, WV). Traps were monitored weekly and lures were replaced each month. Monitoring period began each year between May (2016, 2017) and July (2014, 2015) and ended between the first week of October (2014) and the first week of November (2015 to 2017). Monitoring sites (for both rural and urban habitats) are shown in Figure 1.

The first five adult specimens collected in traps were sent to the Laboratoire d'expertise et de diagnostic en phytoprotection of the Quebec ministry of agriculture (LEDP-MAPAQ) to validate identification and to provide voucher specimens in their collection. Nymphs trapped in 2017 were identified using their "DNA barcode", i.e mitochondrial cytochrome c oxidase 1 (mtCOI) genetic profile from GenBank and the Barcoding of Life Database (Ball and Armstrong 2006; Firlej *et al.* 2013) and haplotype was determined (Gariepy *et al.* 2015; Valentin *et al.* 2017) in order to get insights about their geographical origin.

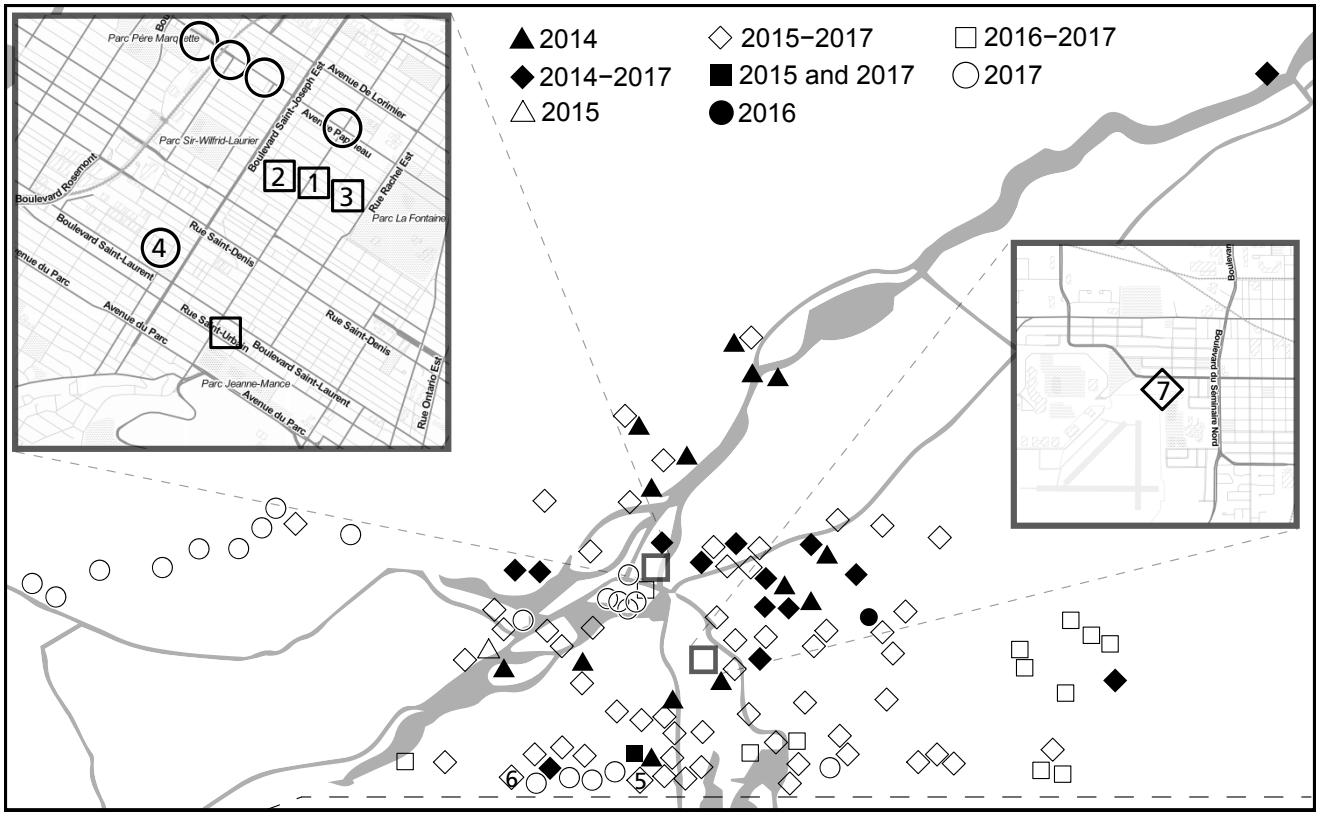

Figure 1. Localization of baited pyramidal traps deployed between 2014 and 2017 in the province of Quebec, Canada. A) partial view of Montreal; B) partial view of Saint-Jean-sur-Richelieu. Numbers refer to traps in which BMSB adults and/or nymphs were captured (Table 1).

In 2014 and 2015, no BMSB was captured. The first specimens to be caught in traps were seven adults, collected from a single trap located in Montreal, on October 5, 2016 (Table 1). In that year, that same trap caught 40 more adults during the month following the first captures. Three other traps in Montreal captured a total of seven adults during the same period. Traps located in other habitats captured no BMSB, with the exception of an adult caught on October 20, 2016 in a trap located next to an apple orchard in Hinchinbrooke (ca. 1.8 km from the first mention in 2014).

In 2017, first adults were caught earlier (June 23 in Saint-Bernard-de-Lacolle and July 5 in Montreal) and a total of nine nymphs (all between third and fifth instars) were also captured on August 30 (four) and September 5 (five) in Montreal, in a single trap located where first adults had been caught in 2016 (Fig. 1A and Table 1: trap #1). All other captures in 2017 (18) were adults. Overall, 55 individuals were captured in 90 traps in 2016 and 27 individuals were captured in 120 traps in 2017. While fewer BMSB were trapped in 2017 despite more traps were deployed than in the previous year, it should be noted that traps were not always installed at the same places each year (Fig. 1) and also that the vast majority of the captures were from one single trap located on a private property subject to human intervention. For these reasons, an in-depth analysis of this data is not advisable to avoid too much speculation.

As summarized by Leskey and Nielsen (2018), BMSB can disperse by various means (flying, crawling, hitchhiking on vehicles) as they seek to meet their nutritional and overwintering requirements. During its initial establishment in the USA, population densities were strongly associated with urban developments and railroads (Wallner *et al.* 2014). Our observations are in accordance with their finding, since overall 96% (79/82) of individuals caught were from urban habitats, while only 20% (27/137) of the traps where located in these habitats.

On a yearly basis, 87% of the 54 adults caught in 2016 in urban habitats were from trap #1. In 2017 again, very few captures (two) were reported in rural areas (in a campground) and 87% of the 25 individuals captured in urban settings were from a single trap, positioned at the same location in Montreal as in 2016. The concentration of Montreal's captures in a single site (68/78 = 87%), combined with the occurrence of nymphs of various developmental stages on that

Table 1. Captures of *Halyomorpha halys* from a network of 137 baited pyramidal traps installed in the province of Quebec, 2014-2017.

Trap #	Locality – borough (coordinates / habitat)	Date (yr-mm-dd)	Adults	Nymphs
1	**Montreal –** Plateau-Mont-Royal	16-09-05	7	0
	(45.528546°N, 73.577164°W / urban)	16-09-09	12	0
		16-09-14	10	0
		16-09-21	13	0
		16-09-28	2	0
		16-10-07	1	0
		16-10-14	2	0
		17-07-05	1	0
		17-08-30	2	4
		17-09-05	1	5
		17-09-12	3	0
		17-10-01	3	0
		17-10-10	1	0
		17-11-03	1	0
2	**Montreal –** Plateau-Mont-Royal	16-09-21	1	0
	(45.528480°N, 73.577047°W / urban)	16-10-07	3	0
		16-10-14	1	0
		16-10-17	1	0
3	**Montreal –** Plateau-Mont-Royal	16-09-14	1	0
	(45.528856°N, 73.576483°W / urban)			
4	**Montreal –** Outremont	17-07-28	1	0
	(45.521062°N, 73.619790°W / urban)	17-08-31	2	0
5	**Saint-Bernard-de-Lacolle**	17-06-23	1	0
	(45.022030°N, 73.469001°W / rural)	17-09-27	1	0
6	**Hinchinbrooke –** Rockburn	16-10-20	1	0
	(45.023107°N, 74.011421°W / rural)			
7	**Saint-Jean-sur-Richelieu**	17-09-26	1	0
	(45.300122°N, 73.270654°W / urban)			
		Total	**73**	**9**

site, also suggests the presence of at least one established population in this area, which has also been suggested by Abram *et al.* (2017). Specimens from this site subjected to barcode analysis, which included four adults collected in 2016 and two nymphs collected in 2017, were from the H1 haplotype. This haplotype is the one that is abundant throughout the eastern USA and in Italy, where BMSB is causing the most severe agricultural and nuisance pest problems (Leskey and Nielsen 2018).

In reaction to these findings and following continued citizen reports in multiple areas of Montreal, city employees have decided to pursue investigations on their territory. In addition to this surveying network, a citizen science project will hopefully be undertaken to help track the spread of BMSB in Quebec and other Canadian provinces. Both measures are needed to monitor the presence of this exotic pest species throughout the northern limits of its eastern North American range.

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