ESTABLISHMENT OF *SCOLYTUS SCHEVYREWI* SEMENOV (COLEOPTERA: CURCULIONIDAE: SCOLYTINAE) IN THE PRAIRIES: LIFE CYCLE, HOSTS AND IMPACT

by

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ABSTRACT

The banded elm bark beetle, *Scolytus schevyrewi,* was first observed in Canada in Alberta in 2006. In 2007, it was found in Manitoba and Saskatchewan. The beetle's hosts include the American elm, *Ulmus americana,* and so, it has the potential to transmit Dutch elm disease, *Ophiostoma ulmi* and *O. novo-ulmi.* In order to learn about the biology of *S. schevyrewi* in the Prairies, the beetle was studied in six communities each year in Manitoba and Saskatchewan in 2009, 2010 and 2011. Baited sticky traps revealed that the adult flight period is from June until October, with a peak in late summer. Unbaited sticky traps and trap logs revealed that stressed Siberian elm, *U. pumila,* is the preferred host. Although *S. schevyrewi* larvae overwintered successfully, only 15% of the overwintering individuals emerged in the spring. The main impact of the invasive beetle is expected to be the killing of stressed Siberian elms. Such trees should be removed to avoid population outbreaks that might result in attacks on healthy Siberian and American elms.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

Since Dutch elm disease was first noticed in Europe around 1920 (Spierenburg 1922 in Holmes and Heybroek 1990), two pandemics of the vascular wilt disease, caused by ascomycete fungi, have killed millions of elms around the world (Gibbs 1978). *Ophiostoma ulmi* (Buisman) Nannfeldt was responsible for the first pandemic which, from its starting point in northwestern Europe, spread to the east and south, going as far as southwest and central Asia (Gibbs 1978). The disease was first noticed in North America in Ohio in 1930 and is thought to have arrived via elm logs shipped from Europe (May and Gravatt 1931; May 1934 in Gibbs 1978). A second pandemic caused by a more aggressive pathogen, *Ophiostoma novo-ulmi* Brasier, started in the 1940s; since then, it has replaced *O. ulmi* and is now found in most of the northern hemisphere (Brasier 1991). Although elms infected with *O. novo-ulmi* were first found in Canada in southwestern Québec in 1944 (Pomerleau 1945), the first recorded outbreaks on the Prairies occurred in 1975 in Manitoba and in 1990 in Saskatchewan (Westwood 1991).

By the time the disease reached the Prairies, it had already killed hundreds of thousands of elms, worth billions of dollars, in northeastern North America (Peacock 1975). The loss of American elm, *Ulmus americana* Linnaeus, trees is more than an economic issue; it is also an aesthetic and practical one. The species has a pleasing vase-like shape (Oswald and Nokes 1979) and can tolerate pollution, soil compaction, drought (Newhouse *et al.* 2007), de-icing salts (Townsend and Douglass 2004), flooding and wind, making it a perfect tree to plant along boulevards (Scheffer *et al.* 2008). Unfortunately, such rows of *U. americana* increase the risk of Dutch elm disease transmission through root grafts (Cuthbert *et al.* 1975); fungi can travel from one tree to another when their roots are grafted, meaning their bark, cambium and vascular system are connected (Epstein 1978).

Dutch elm disease can also be transmitted by many species of bark beetles (Coleoptera: Curculionidae: Scolytinae) (Lanier and Peacock 1981). In the United States, the main vector is the smaller European elm bark beetle, *Scolytus multistriatus* (Marsham) (Barger and Hock 1971). In Canada, this species is found mostly in southern Ontario and south-central Québec (Bright 1976), with records from New Brunswick (Sterner *et al.* 1976), Alberta and British Columbia (Feddes-Calpas 2012) and occasional catches in Manitoba (Buth and Ellis 1981) and Saskatchewan (R. McIntosh, personal communication). However, the survival of *S. multistriatus* is low during the winter months in Canada (Millar *et al.* 1986). The native elm bark beetle, *Hylurgopinus rufipes* (Eichhoff), which occupies almost the same range as *U. americana* (Peacock 1975), is the main vector on the Canadian prairies (Hildahl and Wong 1965). In Manitoba, almost all of the vectoring beetles found are *H. rufipes* (Westwood 1991).

In 2003, the banded elm bark beetle, *Scolytus schevyrewi* Semenov, an invasive species, was found and identified for the first time in the United States (Liu and Haack 2003). Two years after these catches in Colorado and Utah, *S. schevyrewi* was caught from coast to coast (Negrón *et al.* 2005). Due to the rapid spread of the species, museum collections were searched and it was found that *S. schevyrewi* had previously been undetected in the United States and had been present, at least since 1994, in Colorado (Negrón *et al.* 2005). The beetle occurs naturally in central Asia and China (Michalski

1973) and it is not known how it was introduced in North America (Lee *et al.* 2009). Spreading from the western United States, where it probably first arrived (Negrón *et al.* 2005), *S. schevyrewi* reached southern Alberta in 2006 (Langor *et al.* 2009) and the other two prairie provinces as well as southern Ontario the following year (CFIA 2007). The latest new record of *S. schevyrewi* in a province was for British Columbia in 2010 (Humble *et al.* 2010).

The purpose of the thesis research was to learn about the biology of *S. schevyrewi* on the Canadian prairies. To do so, field work was conducted in Saskatchewan and Manitoba on adult beetles as well as their brood. By-catches of most field studies included *H. rufipes* and the eastern ash bark beetle, *Hylesinus aculeatus* Say, and data on these beetles are presented in appendices at the end of this thesis. Data on *H. rufipes* will be compiled into a forthcoming publication, but are not a central focus of the thesis. The thesis focus is on the biology of *S. scheyvrewi* and implications of this beetle's arrival in the Prairie Provinces. The thesis follows the conventional style of introduction, methods, results and discussion.

LITERATURE REVIEW

Scolytus schevyrewi morphology and life cycle

Scolytus schevyrewi is a member of the genus *Scolytus* Geoffroy (Michalski 1973), which is within the tribe Scolytini Latreille, itself within the subfamily Scolytinae Latreille (Alonso-Zarazaga and Lyal 2009). The subfamily Scolytinae was until recently classified within the family Scolytidae (Bright 1976). However, the new convention places all bark beetles within the family Curculionidae, as the subfamily Scolytinae (Kuschel *et al.* 2000; Oberprieler *et al.* 2007; Alonso-Zarazaga and Lyal 2009). In this thesis, the use of the term Scolytinae will follow the new nomenclature. There are a few synonyms of *S. schevyrewi: Eccoptogaster schevyrewi* var. *sinensis* Eggers, *Eccoptogaster frankei* Wichmann, *Eccoptogaster emarginatus* Wichmann, *Eccoptogaster transcaspicus* Eggers, and *Scolytus seulensis* Murayama (Michalski 1973).

Both male and female adult *S. schevyrewi* are about 3–4 mm long (Wang 1992; LaBonte 2010). Except for the elytra, the body is shiny and dark brown to black (Michalski 1973). The elytra are reddish-brown to dark brown with, in most individuals, a darker band between the middle and the apex (Wang 1992). Rows of punctures run from the base of the elytra to their apex (LaBonte 2010). A spine of varying shape is usually present on the second abdominal sternite, but it is not located on the anterior part of the sternite as is the case in *S. multistriatus* (LaBonte 2010). Setae on the third, fourth and fifth abdominal sternites are short and recumbent (LaBonte 2010). The legs and antennae are reddish-brown (Michalski 1973). Fan *et al.* (2011a) have described the antennal morphology as well as the distribution and type of sensillae present on them.

The adults, when seeking hosts, avoid flying long distances and colonize trees near the ones from which they emerged (Liu and Haack 2003). Suitable hosts are located by male and female *S. schevyrewi* using tree volatiles (Lee *et al.* 2010). The production of aggregation pheromones once a host is found has not been detected, but if an aggregation pheromone is produced later on, it might only be effective synergistically with the host's volatiles (Lee *et al.* 2010).

On the host, females burrow in the bark and dig an individual egg gallery in the phloem, along the wood grain (Wang 1992). Galleries can be constructed in the trunk and in branches with a diameter of ≥ 3 cm; however, about 47.7% of *S. schevyrewi* found in a dissected tree were in the "bottom part" (Yang *et al.* 1988). Males search for entrance holes on the bark surface and mating occurs at the entrance of the galleries (Wang 1992). Males can mate with more than one female (Wang 1992). Yang *et al.* (1988) report that females can mate multiple times as well. In the autonomous region of Xinjiang, northwestern China, where the annual temperature averages 11.7°C and the mean annual precipitation is 150 mm (China Culture 2003), Wang (1992) counted 23–123 eggs per gallery with an average of over 60 eggs and Li *et al.* (1987) counted 46–75 eggs per gallery. In the autonomous region of Ningxia, northern China, where the annual temperature averages 5–9°C and the mean annual precipitation is 180–680 mm (China Culture 2003), Fan *et al.* (2011b) counted 40–80 larval galleries associated with individual maternal galleries. In the province of Shaanxi, central China, where the annual temperature averages 7–16°C and the mean annual precipitation is 340–1240 mm (Travel China Guide 2012), Yang *et al.* (1988) counted 21–51 eggs per gallery with an average of

34 eggs per gallery. At a constant 25°C in laboratory conditions, Lee and Seybold (2010) counted 19.5 ± 1.5 eggs per gallery. After having laid their eggs in niches along their gallery, females position themselves at the entrance of the gallery until they die (Wang 1992).

The larval galleries start out perpendicularly to the maternal gallery (Wang 1992). Eventually, the pattern becomes more random and larvae can cross the paths of other larvae (Wang 1992). The larvae sometimes reach the xylem (Yang *et al.* 1988). When there are many larvae present, they can completely destroy the cambial region (Yang *et al.* 1988). The final instar larvae migrate to the outer bark and construct pupal chambers (Wang 1992). Wang (1992) and Fan *et al.* (2011b) suggest that *S. schevyrewi* has five larval instars; however, Wang (1992) does not mention the source of this information. As for Fan *et al.* (2011b), they present larval head width measurements that do not increase at a constant ratio in successive instars as would be predicted by Dyar's rule (Dyar 1890). Nevertheless, it is possible that *S. schevyrewi* has five larval instars, like its congeners *S. scolytus* (Fabricius), *S. multistriatus,* and *S. intricatus* (Ratzeburg) (Yates 1984).

In Xinjiang, *S. schevyrewi* completes one generation in 40–45 days under field conditions (Wang 1992). At 26°C, Wang (1992) found that it takes an average of 30.8 days from oviposition until adult emergence: 3–5 days for the egg stage, 18–23 days for the larval stage and 5–7 days for the pupal stage. At the same temperature, Wang and Chen (2000) observed that the adult stage lasts 14–43 days and 6–29 days for females and males, respectively. However, neither Wang (1992) nor Wang and Chen (2000) present data on the number of days between the emergence of adults and oviposition. Fan *et al.* (2011b) found that the larval and pupal stages last 20–27 and 5–12 days, respectively, at an unspecified temperature. With logs placed in a wood shed that "moderated the temperature" (Negrón *et al.* 2005, p. 87), the authors observed a duration of less than 30 days from logs being infested until adult emergence; however, they believe that *S. schevyrewi* development would take longer in the field as a result of less favourable environmental conditions. At 18°C, Wang and Chen (2000) observed that the egg and pupal stages last an average of 13.2 days and 28.5 days, respectively, but do not provide any information on the duration of the larval stages; the adult stage lasts an average of 33.8 days for females, and 22.5 days for males.

In China, *S. schevyrewi* has two or three generations that overlap (Yang *et al.* 1988, Wang 1992). Fan *et al.* (2011b) observed that, in Ningxia, 98.2% of the overwintering beetles are mature larvae and 1.8% are pupae. Wang (1992) states that *S. schevyrewi* overwinters as a mature larva in Xinjiang. *Scolytus schevyrewi* also overwinters as a larva in Shaanxi (Yang *et al.* 1988), but although the authors are the only ones to report that *S. schevyrewi* can overwinter as an adult, they do not mention the pupal stage as another overwintering stage. The number of generations and overwintering stages are believed to be the same in the United States (Lee *et al.* 2007).

In Ningxia, overwintering larvae pupate in early May with a peak in mid-May (Fan *et al.* 2011b). The adults begin emerging in late May (Table 1) with a peak in early June (Fan *et al.* 2011b). Eggs are laid in June and the first larvae hatch in the middle of the month. Larvae from the first generation pupate in July and emergence of the adults peaks in late July, but continue until early August (Fan *et al.* 2011b). In this region, a few larvae from the second generation pupate in September (Fan *et al.* 2011b) and it is likely that the adults found in dissected *U. pumila* in September and early October are actually second generation adults and not first generation adults taking more time before emerging (Table 1).

In Xinjiang, overwintering larvae start pupating in early April when the temperature reaches 15°C; pupation peaks in mid-April and, around that time, the first adults start to emerge and numbers peak in early May (Li *et al.* 1987; Wang 1992). In Shaanxi, the first adults do not emerge until mid-April or May (Yang *et al.* 1988). Larvae from the first generation hatch in late April, pupate in late May and the adults emerge in mid-June (Yang *et al.* 1988). The second generation of adults emerges in early August (Yang *et al.* 1988). In Xinjiang, the first generation larvae pupate in late May and early June; the adult emergence peaks in early July and continues until early August (Li *et al.* 1987; Wang 1992). Second generation larvae usually overwinter, but some of them pupate and become the third generation of the year (Wang 1992). Wang and Chen (2000) observed that adults from the third generation could lay eggs and that the brood overwinters successfully.

After emergence, it is believed that the adult beetles feed in the crotches of tender twigs of healthy trees (Witcosky 2004). Yagdyev (1979) is the only author to mention adults feeding on the leaves. However, this statement could be based on a misidentification; there is no mention of leaf feeding by scolytines in Bright (1976). There are reports of stressed trees being killed as a result of the repeated attacks of *S. schevyrewi* in the United States and in China (Wang 1992; Negrón *et al.* 2005).

In Shaanxi, the braconid parasitoid *Elachistocentrum* sp. (Hymenoptera: Braconidae) parasitizes 6.9% of *S. schevyrewi* larvae (Yang *et al.* 1988). In Xinjiang, a *Cheiropachus* sp. (Hymenoptera: Pteromalidae) and a braconid species parasitize from 14.0% to 42.4% of the larval population (Wang 1992). *Cheiropachus quadrum* (Fabricius) was reared from *S. schevyrewi* in Colorado (Negrón *et al.* 2005). Fan *et al.* (2011b) also report predation by *Thanasimus* sp. (Coleoptera: Cleridae), *Labidura* sp. (Dermaptera: Labiduridae) and the ectoparasitic mite *Pediculoides ventricosus* Newport (Acariformes: Pediculoidae).

***Scolytus schevyrewi* hosts**

In its native range, *S. schevyrewi* is mostly associated with *Ulmus* species, but has also been collected from species of *Caragana, Elaeagnus, Malus, Prunus, Pyrus* and *Salix* (Michalski 1973; Yang *et al.* 1988; Wang 1992; Bright and Skidmore 2002; Negrón *et al.* 2005). However, it is thought that of all these genera, only *Ulmus* is colonized by *S. schevyrewi* (Lee *et al.* 2011). In the United States, the only tree species from which the beetle has been collected are in this genus: *U. americana, U. pumila* Linnaeus, *U. thomasii* Sargent and *U. procera* Salisbury (Negrón *et al.* 2005). In a no-choice experiment in which *S. schevyrewi* adults were given the opportunity to colonize *U. americana, U. parvifolia* Jacquin, *Caragana arborescens* Fabricius, *Prunus fontanesiana* (Spach) C.K. Schneider or *Elaeagnus angustifolia* Linnaeus, *U. americana* logs were the only ones to be colonized (Lee *et al.* 2011).

Scolytus schevyrewi was successfully reared from *U. americana* logs (Jacobi *et al.*

2007; Johnson *et al.* 2008); but whereas Jacobi *et al.* (2007) specify that the logs were from an *U. americana* infected with *O. novo-ulmi,* Johnson *et al.* (2008) do not give any details on the condition of the trees from which they got their logs. *Ulmus pumila* infested with *S. schevyrewi* were also used as a source of adult beetles, but neither Lee *et al.* (2010), Lee and Seybold (2010) nor Fan *et al.* (2011b) mention if these trees were stressed prior to the infestation. Shi and Chen (1990) observed that the condition of young *U. pumila* trees has an impact on their suitability to beetles. *Scolytus schevyrewi* adults attempted to colonize healthy *U. pumila,* but failed; the beetle was only successful with weakened *U. pumila* (Shi and Chen 1990). Wang (1992) suggests that live hosts that are declining can be used by *S. schevyrewi,* but that a smaller proportion of the brood would survive to adulthood than in recently dead hosts. The cause of the host's decline is not important (Shi and Chen 1990); however the ideal host for breeding is one that has recently died, and has its bark intact and no internal sap flow (Wang 1992).

Implications of *S. schevyrewi* establishment in the Prairies

Dutch elm disease

The biology of Dutch elm disease is described in Campana (1978); a summary of the author's description follows. *O. novo-ulmi* spores enter the xylem of healthy elms through root grafts or wounds created by elm bark beetle vectors. The spores reproduce and travel passively through the vascular system; such movement, and as a result the establishment of the pathogen, is facilitated in larger vessels. *O. novo-ulmi* can also infect adjacent vessels by moving through pit membranes or openings created by the disintegration of cell walls. Fungal growth impedes the movement of water in the xylem; this can eventually cause the death of leaves, shoots, or the entire tree, depending on the site of infection. However, the pathogen may be isolated in infected vessels by tyloses that plug such vessels (MacHardy 1978). These tyloses are outgrowths of parenchyma cells through pit membrane into neighbouring infected vessels (Van Alfen and MacHardy 1978).

Dutch elm disease vectoring capabilities

Repeated *S. schevyrewi* attacks can kill stressed trees (Wang 1992; Negrón *et al.* 2005), but in addition, hazard to trees can occur if the beetle can vector Dutch elm disease (Harris 2004; Negrón *et al.* 2005; Koski and Jacobi 2007). It was shown that *S. schevyrewi* adults emerging from infected *U. americana* wood can carry *O. novo-ulmi* spores (Harris 2004). It was also shown that the percentages of adults that emerged from this material and carried spores, sometimes over 80%, are similar to those of *S. multistriatus* adults (Negrón *et al.* 2005), the most important Dutch elm disease vector in the United States (Barger and Hock 1971). Koski and Jacobi (2007) have demonstrated in field cages, and in the laboratory, that *S. schevyrewi* can transfer *O. novo-ulmi* spores to feeding wounds on *U. americana* branches; however, no Dutch elm disease symptoms were observed on these branches and nothing has been published on *O. novo-ulmi* transmission by *S. schevyrewi* since this abstract appeared in 2007. The beetle might be unable to act as a vector of the disease.

Scolytus multistriatus adults, like *S. schevyrewi* adults, may feed in twig crotches of healthy elms after they have emerged (Kaston and Riggs 1938; Witcosky 2004). As for *H. rufipes* adults, there are instances of their feeding in the same manner, although they typically feed on the trunk or branches of healthy elms (Kaston and Riggs 1938). They can also feed on healthy elm bark in their overwintering tunnels, which they extend, before emerging (Kaston and Riggs 1938; Peacock 1975). During their feeding activities, *S. multistriatus* and *H. rufipes* adults may reach the xylem (Parker *et al.* 1948; Lanier and Peacock 1981) and it is likely that *S. schevyrewi* adults do as well.

Bark beetles carrying *O. novo-ulmi* spores can infect the host if they reach the xylem (Collins 1941; Webber 1987). Spores may be transferred to the fresh wound and germinate into mycelia that can eventually enter the vascular system of the host tree (Webber 1990). The fungus produces yeast-like spores that spread within the tree through the vascular system (Booth and Gibson 1973). *Ulmus americana* is vulnerable to such infections from spring to fall (Pomerleau 1965); however, the species is most vulnerable when new spring growth occurs (Takai and Kondo 1979).

This production of new, larger spring vessels has not yet occurred when *H. rufipes* adults, that in Manitoba typically would have overwintered as adults, extend their tunnels to feed before they emerge (Parker *et al.* 1948; Anderson 1996). Feeding by *H. rufipes* following emergence from their overwintering sites is the most likely to result in spore transmission as new vessels have been produced by trees at that time (Collins 1941). However, the new generation adults are more attracted to healthy elms when they emerge in the summer than the overwintering adults are in the spring (Swedenborg *et al.* 1988). *Scolytus multistriatus* adults emerging from their overwintering sites also feed during the time of spring vessel production (Parker *et al.* 1941). Comparing *S. multistriatus* and *H. rufipes,* the first species is the most effective vector as it usually feeds in more parts of the tree canopy than the second (Westwood 1991).

In locations where *S. multistriatus* and *S. scolytus* occur, the latter is the largest and most effective vector; larger elm bark beetle species, with their greater surface area, have the potential to carry more *O. novo-ulmi* spores (Webber 1990). At a length of 2–3 mm, *S. multistriatus* is also smaller than *S. schevyrewi* (Bright 1976; LaBonte *et al.* 2003). However, the way *S. multistriatus* and *S. scolytus* breed also affects their effectiveness as vectors (Webber 1990). Whereas *S. scolytus* pupates in the inner bark of its host, both *S. multistriatus* and *S. schevyrewi* pupate in the outer bark of their host (Wang 1992; Moser *et al.* 2010). The concentration of fungal spores present in the moist inner bark is greater than the concentration present in the drier outer bark; thus the likelihood of contact between the beetles and the pathogen is reduced for *S. multistriatus* and *S. schevyrewi* (Moser *et al.* 2010).

If the preferred host of *S. schevyrewi* in the Prairies is *U. pumila* as it is in the United States (Lee *et al.* 2010), the beetle might not come in contact with *O. novo-ulmi* spores because *U. pumila,* like other Asian *Ulmus* species, is resistant to Dutch elm disease (Heybroek 1981). However, *U. pumila* is thought not to be equally resistant throughout its native range; it is more resistant in arid regions, where the diameter of its vessels is smaller (Brasier 1990). The blocking of narrow vessels by tyloses is more effective at restricting the movement of spores within the host than that of wider vessels (McNabb *et al.* 1970). With an annual total precipitation average of 201–600 mm, the Prairies are a relatively dry region of Canada (NRC 2009) and it makes sense that Dutch elm disease symptoms would seldom or never be observed on *U. pumila* growing in Manitoba and Saskatchewan (I. Pines and R. McIntosh, personal communication). However, it is not known whether the lack of symptoms means that *U. pumila* trees are not infected or are an asymptomatic reservoir for *O. novo-ulmi.*

If *S. schevyrewi* were to colonize host trees other than *Ulmus* species from the list in Negrón *et al.* (2005), it might not come in contact with *O. novo-ulmi* spores either. However, tree species appearing on the list could have been accidental attacks as were observed with *S. multistriatus* on a *Populus* species (Allen and Humble 2002; Bright and Skidmore 2002), *S. kirschi* Skalitzky on *Fraxinus excelsior* Linnaeus, *Populus alba* Linnaeus and *Prunus* species (Balachowsky 1949; Michalski 1973), and *H. rufipes* on *Fraxinus, Prunus* and *Tilia* species (Bright 1976).

Trees in the genus *Ulmus* are the main hosts for *H. rufipes* (Bright 1976) and although the beetle can overwinter in *U. pumila* in Manitoba, most do so in *U. americana* (Anderson and Holliday 2000). In Manitoba, *H. rufipes* adults overwinter at the base of healthy *U. americana* (Anderson 1996). The proportion of the population that overwinters successfully above 55 cm from the ground is very small (Anderson and Holliday 2003). Killing overwintering *H. rufipes* is one of the main components of Dutch elm disease management programs in Manitoba (Westwood 1991). The application of residual insecticides to the base of *Ulmus* trees to kill these beetles is an effective control method (Gardiner and Webb 1980). If *S. schevyrewi* were to be an *O. novo-ulmi* vector and if it overwinters in most parts of its host as it does for breeding (Yang *et al.* 1988), basal spraying might not be as effective against this beetle as it is for *H. rufipes*. Also, *S. schevyrewi* could have more than one generation in the Prairies and, as a result, individuals carrying *O. novo-ulmi* spores could be emerging from their host during other periods than in spring, when *H. rufipes* adults emerge from their overwintering sites (Kaston 1939). A new vector with multiple generations could greatly affect the desirable time for infected tree removal and therapeutic pruning, currently used in management of *H. rufipes.* The latter should not be done until the end of the summer in regions where *H. rufipes* is the only vector present (Landwehr *et al.* 1981). However, Landwehr *et al.* (1981) recommend that therapeutic pruning should be carried out in the late fall or in the winter in areas where *S. multistriatus* is the main vector. Regarding the removal of suitable hosts for breeding, these trees should be destroyed before the beetles emerge (Neely 1975; Veilleux *et al.,* 2012).

Displacement of H. rufipes

In locations where *H. rufipes* occurs with *S. multistriatus,* an exotic species (Chapman 1910), and where the latter can successfully overwinter, *S. multistriatus* is considered to have displaced *H. rufipes* (Lanier 1983). A similar phenomenon seems to be happening in locations where *S. multistriatus* and *S. schevyrewi* occur (Lee *et al.* 2010). In states where *S. schevyrewi* has probably been present for longer, the numbers of *S. multistriatus* caught during surveys were lower than they had been in surveys conducted prior to the establishment of *S. schevyrewi* (Lee *et al.* 2009). *Scolytus schevyrewi* females lay more eggs than *S. multistriatus* females and *S. schevyrewi* larvae are better competitors in *U. pumila* logs colonized by both species, probably because they consume more of the host resource and take up more space with their galleries than *S. multistriatus* larvae (Lee and Seybold 2010). In *U. americana* logs used for rearing *S. schevyrewi* and *S. multistriatus,* Jacobi *et al.* (2007) found that in logs colonized by both species, 98% of the emerging adults were *S. schevyrewi.* Finally, Lee *et al.* (2010) suggest that *S. schevyrewi* adults can colonize suitable hosts in greater numbers than *S. multistriatus* adults.

Conclusion and research objectives

Scolytus schevyrewi may be causing the displacement of *S. multistriatus,* a species that is thought to have caused the displacement of *H. rufipes* in regions where the two occur. If *S. schevyrewi* is actually displacing *S. multistriatus,* perhaps it could displace *H. rufipes* too. Such information is unavailable at the moment. Information regarding the biology of *S. schevyrewi* in the Prairies is not available either. Most of the research on this beetle to date has been conducted in China and the United States. The beetle has a similar life cycle to that of *S. multistriatus* (Jacobi *et al.* 2007), the main Dutch elm disease vector in North America (Westwood 1991); both species feed in twig crotches of healthy elms (Kaston and Riggs 1938; Witcosky 2004) and can have multiple generations (Bright 1976; Wang 1992). Also, *S. schevyrewi* might not overwinter at the base of its hosts as is the case for *H. rufipes* (Anderson 1996). If *S. schevyrewi* is a vector of *O. novo-ulmi,* authorities might have to modify their Dutch elm disease management programs. Even if the beetle would prefer *U. pumila* on the Prairies as it does in the

United States (Lee *et al.* 2010), authorities might still have to review their management programs as the beetle could still come in contact with *O. novo-ulmi* spores in this host tree. On the other hand, if *S. schevyrewi* is not a vector of the pathogen or if *U. pumila* in the Prairies is not infected by *O. novo-ulmi,* the establishment of *S. schevyrewi* might not be a problem in terms of Dutch elm disease management; however, the beetle is able to kill weakened elm trees (Wang 1992; Negrón *et al.* 2005).

To acquire the needed information, the objectives of this research project are to investigate the distribution of *S. schevyrewi* in the Prairies, to determine the number of generations it has and assess what stages overwinter. Other parts of the project are designed to learn about the host tree selection of *S. schevyrewi.* Finally, experiments should provide information regarding the interactions between *S. schevyrewi, H. rufipes,* suitable *S. schevyrewi* hosts and *O. novo-ulmi.*

TABLE 1. Presence of the life stages of different *Scolytus schevyrewi* generations in dissected *Ulmus pumila* throughout the year in the county of Yanchi, Ningxia, China (translated from Fan *et al.* (2011b, p. 660)). In 2008, 2009, and 2010, 5–6 infested trees were cut for dissection three times per month. Symbols: larval stage (○), pupal stage (×), adult stage (●), and egg stage (·).

GENERATION	MONTH[a]											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
OVERWINTERING[b]	○○○	○○○	○○○	○○○	○○○							
	×××	×××	×××	×××	×××							
					●	●●●						
FIRST						· · ·						
						○○	○					
							×××					
							●●●	●●●	●●●	●		
SECOND							· ·	· ·				
							○	○○○	○○○	○○○	○○○	○○○
								×××	×××	×××	×××	×××

[a] For each month, observations were made at the beginning of the month, midway through the month, and at the end of the month.

MATERIALS AND METHODS

Field studies were carried out in the summers of 2009, 2010 and 2011 in Saskatchewan and Manitoba communities (Table 2). *Scolytus schevyrewi* had been collected in these communities prior to their being chosen for the project (Oghiakhe and Holliday 2009; R. McIntosh and I. Pines, personal communication). Dutch elm disease occurs in all Manitoba communities chosen and, in each year of the project, in one of three selected communities in Saskatchewan. All laboratory experiments and procedures were carried out at the University of Manitoba in Winnipeg.

Baited sticky traps

Baited sticky traps (Fig. 1) were used to learn about the flight period and distribution of *S. schevyrewi.* Contech's (Contech Enterprises Inc., Victoria, British Columbia) panel traps (catalogue number 300000099, 2011) (44.2 cm × 67.4 cm) were used whenever possible. However, Great Lakes IPM's (Great Lakes IPM, Inc., Vestaburg, Michigan) elm bark beetle traps (catalogue code IPM-BBT-12, 2012) (45.7 cm × 63.6 cm) were used for most of the trapping period in Otterburne and Saint-Adolphe in 2009. That same year in La Salle and in 2010 in Otterburne and Saint-Adolphe, these traps were used for five or six weeks. In 2011, elm bark beetles traps were used for a single week in Otterburne and Saint-Adolphe. Contech's elm bark beetle lures Eppendorf custom were used (catalogue number 300000097, 2011) in all communities in all years. Baits were attached at the centre of the sticky traps and changed halfway through the summer so that they would never exceed their life expectancy of 90 days.

There were three baited sticky traps per community. The traps were stapled to utility poles at 2 m from the ground and facing north so that the baits were less exposed to the sun and would last longer (R. McIntosh, personal communication). Utility poles with traps were at least 25 m apart, did not have transformers or street lights, and were at least 10 m from *U. pumila* and *U. americana* trees. All potential host trees listed by Negrón *et al.* (2005) within 50 m were recorded. Baited sticky traps were normally changed once a week from the beginning of the trapping period in May or June until the end of October. Where there was a longer interval between collections, catches were divided by the interval duration to give a value on a per week basis. Community, trap location, and collection date information were recorded on each trap then wax paper was placed on the sticky side of used traps and traps were stored at 4°C in the laboratory until they were checked for bark beetle catches.

After having removed the wax paper, the sticky traps were carefully checked and the numbers of *S. schevyrewi* found were recorded. Although only 20 *S. schevyrewi* adults per community and year were eventually plated to check for *O. novo-ulmi* growth, tweezers used to pick these adults were always sterilized between each pick to avoid cross-contamination of spores. Monoject Scientific's (Monoject Scientific, Sherwood Medical, St. Louis, Missouri) Bacti-Cinerator III was used most of the time, but 70% isopropyl rubbing alcohol was used when the device was unavailable. Beetles were placed individually into carefully labelled microcentrifuge vials and stored at 4°C.

Unbaited sticky traps

Unbaited sticky traps (Fig. 2) were used to learn about tree selection by adult *S. schevyrewi.* Unbaited sticky traps were usually Contech's panel traps cut in halves to produce trap surfaces of 44.2 cm × 38.7 cm; at this size, traps were more likely to fit on trees with a smaller diameter and trees with branches coming out of the trunk. For six weeks in 2009 in La Salle and two weeks in 2010 in Carman, Great Lakes IPM's elm bark beetle traps were used, and were cut to 45.7 cm × 36.8 cm.

In all communities chosen for this study, there were three host tree species (from among those listed in Negrón *et al.* 2005) and, for each host tree species, five were chosen on which to put unbaited sticky traps. Normally, the species were *Salix alba* Linnaeus, *U. americana* and *U. pumila,* but where *S. alba* was not available, unbaited traps were stapled to *E. angustifolia* instead. Other potential host trees within 50 m were recorded. Traps were stapled high enough so that they would be above the understorey; on trees in riparian forest, the traps were oriented towards the river. Unbaited sticky traps were changed once every two weeks from the beginning of the trapping period in May or June until the end of October. Once removed, traps were packed and processed using methods consistent with those described for baited sticky traps.

In 2011, a new experiment was designed to test whether stressed *U. pumila* are more attractive than healthy *U. pumila.* Chosen *U. pumila* were girdled. The cut was deep enough so that it would reach the surface of the xylem. In Carman and Swift Current, each girdled tree was paired with a healthy *U. pumila.* Trees within each pair were separated by ≤ 20 m and distance between pairs was ≥ 20 m. Unbaited sticky traps were stapled to five pairs of *U. pumila* in Carman and to three pairs of *U. pumila* in Swift

Current. Unbaited traps were also stapled to four girdled *U. pumila* in Weyburn. However, these girdled trees were not paired with healthy *U. pumila* as there were not enough trees available. Traps were changed every two weeks and processed as described above.

Trap logs

Trap logs were used to investigate host tree selection by adult *S. schevyrewi.* In early May of the three years of the project, trap logs of *S. alba, U. americana* and *U. pumila* were cut. In Swift Current, where *S. alba* trap logs were not available, *E. angustifolia* trap logs, and in 2010 a few *C. arborescens* trap logs, were used instead of *S. alba.* All species appear on the list of host trees in Negrón *et al.* (2005). Trap logs of all species were about 50 cm long and most had a diameter of about 15 cm, all were ≥ 5 cm in diameter.

All trap logs were deployed at the end of May. For each year, there was one site in Manitoba and one or two sites in Saskatchewan (Table 2). In 2009 in Manitoba, the trap logs were deployed in a riparian forest near La Salle. In 2009 in Saskatchewan, and in both provinces in 2010 and 2011, the trap logs were deployed in open areas. Trap logs were on the ground and held in a vertical position (Fig. 3).

At the beginning of July, August, September, and October, six logs of each species from each site were collected and brought back to the laboratory where they were stored at 4°C until processing. No logs were brought back to the laboratory in July in 2009. In 2010, an extra set of six logs was brought back to the laboratory at the beginning of November.

In 2009 and 2010, 12 trap logs of each species were left in the field until the beginning of winter to learn about the overwintering biology of *S. schevyrewi.* Following at least five consecutive days of below 0°C maximum temperature, these last trap logs were removed from the field. For each species, six logs were stored at 4°C until processing and another six were put in an outdoor roofed insectary on the campus of the University of Manitoba. To record temperatures in the piles of logs stored outside in the insectary during the winter of 2010–2011, thermocouples connected to six data-loggers were placed in the pile of logs. Logs stored outside in the insectary were brought to the laboratory at the end of the following March.

Dissection

Three of the six trap logs of each species brought back from each site were dissected to learn about the development stages present at the time of removal from the site. When ready for dissection, each trap log was taken out of the 4°C storage chamber. Using chisels and hammers, the bark of these logs was removed carefully. The bark was chipped into small pieces in order to find beetles at different stages. *Scolytus schevyrewi* adults that were found were picked out with tweezers and put individually into microcentrifuge vials. Larvae and pupae were picked out in the same manner and were preserved individually in microcentrifuge vials and stored at 4°C in 70% ethanol. The numbers of galleries, larvae, pupae and adults were recorded for each trap log.

In Swift Current in 2010, one log of each species for each collection date had been covered in arc yellow fluorescent powder (product code AX-16, colour code 9307-A) from Monteith (A.R. Monteith Corporation, Mississauga, Ontario) when the trap logs were deployed. In 2011, all logs from Carman and Swift Current that were to be dissected were covered in fluorescent powder. This was to allow adults found in dissected trap logs to be separated into marked parents and unemerged adults that had developed from brood and would not have contacted the powder. All adults from these logs were examined under a binocular microscope using a Blacklight Blue ultraviolet fluorescent lamp (product number 21625, 2012) by Sylvania (Osram Sylvania, Danvers, Massachusetts) and the number of marked and unmarked adults was recorded.

Emergence cylinders

The remaining three trap logs of each set of six brought back to the laboratory were placed in emergence cylinders (Fig. 4) to see if *S. schevyrewi* could complete development in the trap logs. Cylinders (123 cm × 52 cm) had capped ends and were made of cardboard. One glass jar lid (11 cm in diameter) was screwed to the cap at one end of each cylinder and a hole was punched through both. Emergence cylinders were placed horizontally, and a single log was placed in each cylinder. Caps were put back on the cylinders and glass jars (26 cm × 16 cm) were screwed to their lids. Moist paper towel was placed in the glass jars.

Every two days, each glass jar was removed and checked for emerged *S. schevyrewi* adults and their numbers were recorded; the adults were put individually in microcentrifuge vials to be stored in a chamber at 4°C. Before reattaching the glass jars, the paper towel was moistened and water was sprayed into the emergence cylinder. From

March in 2010 and 2011, the same procedures were followed for all trap logs that had remained in the insectary all winter.

When a period of two weeks with no emergence had occurred for a batch of logs in emergence cylinders, the logs were taken out of the cylinders and stored at room temperature until they were dissected as described above.

Development time

In 2011, to investigate the rate of development of *S. schevyrewi* in relation to temperature, fresh *U. pumila* logs, along with 20 active *S. schevyrewi* adults marked with a yellow Posca pen (Uni Mitsubishi Pencil Co. UK, Ltd., Worcester, United Kingdom, catalogue code PC-5M, 2008), were put in tied clear plastic bags in incubators set to five different constant temperatures ranging from 15°C to 35°C at 5°C intervals. Lights were on for 12 hours. There were two bagged logs for each temperature regime. The bags were opened and checked daily for *S. schevyrewi* adults. Beetles were removed from each bag before resealing it. The numbers of unmarked adults were recorded along with the number of days elapsed since the log and beetles were put in the incubator.

Statistical methods

Systat 13 (Systat 2008) was used to perform all the statistical analyses for this project and the α-level used for all analyses was 0.05. For sticky traps, data from traps from the two manufacturers were pooled for analysis. For parametric statistical tests, graphic inspection of residuals was used to assess the need for, and adequacy of, transformations.

When a transformation was needed, $\log_{10}(x + 1)$ was used.

A first analysis of variance (ANOVA) was performed using the total numbers per trap for baited sticky traps for each year separately. After this first analysis, data for 2009 were analyzed separately to investigate the effects of provinces and of communities within provinces. In 2010–2011, communities were the same for both years and so a repeated measures ANOVA of total catch per trap for the two years was conducted to test for the effects of provinces and communities within provinces, and between-year effects.

For the paired *U. pumila* experiment, a split plot ANOVA was performed on total catch per unbaited trap. The subplot was pair of trees with traps, to accommodate the paired design as well as the two communities in which the paired study was performed.

Likelihood ratio χ^2 tests were performed to determine whether frequency of colonization of trap logs by *S. schevyrewi* was affected by log species, year and community. Beetles' survival in these logs was investigated using the same method. To test whether the distributions of *U. pumila* trap log diameters that were colonized and not colonized by *S. schevyrewi* were different, a Kolmogorov-Smirnov two-sample test was conducted.

TABLE 2. Communities in Manitoba and Saskatchewan where sticky traps and trap logs were deployed in each of the three study years.

PROVINCE	COMMUNITY	STUDY								
		BAITED STICKY TRAPS			UNBAITED STICKY TRAPS			TRAP LOGS		
		2009	2010	2011	2009	2010	2011	2009	2010	2011
MANITOBA	CARMAN[a]		X	X		X	X		X	X
	LA SALLE[a]	X	X		X			X		
	OTTERBURNE[a]	X	X	X						
	SAINT-ADOLPHE[a]	X	X	X						
SASKATCHEWAN	ASSINIBOIA	X						X		
	ESTEVAN[a]	X			X					
	MAPLE CREEK	X	X	X						
	SWIFT CURRENT		X	X		X	X		X	X
	WEYBURN[a]		X	X		X	X		X	

[a] Dutch elm disease is established in these communities.

FIG. 1. Baited sticky trap on a utility pole in Swift Current, SK.

FIG. 2. Unbaited sticky trap on a *Ulmus americana* in La Salle, MB.

FIG. 3. Trap logs of *Salix alba, Ulmus americana* and *U. pumila* deployed in a field in Carman, MB.

FIG. 4. Emergence cylinders.

RESULTS

Baited sticky traps

The pooled catches of *S. schevyrewi* from Great Lakes IPM and Contech sticky traps are shown in Table 3. In 2009, the number of *S. schevyrewi* caught on baited sticky traps was significantly greater in Saskatchewan than in Manitoba ($F_{1, 18} = 16.04$, $p < 0.001$, $\log_{10}$ transformed analysis of variance), but the variation among the communities within each province was not significant ($F_{4, 18} = 1.78$, $p = 0.176$) (Table 4).

As there were no catches in 2009 and 2010 in La Salle, the 2010 data from La Salle was excluded from analysis so that chosen communities would be the same in both 2010 and 2011 and a repeated measures analysis of variance could be conducted. In 2010 and 2011, as was the case in 2009, the number of *S. schevyrewi* caught on baited sticky traps was significantly greater in Saskatchewan than in Manitoba ($F_{1, 12} = 16.09$, $p = 0.002$, $\log_{10}$ transformation) (Table 4). However, the variation among the communities within each province was also significant ($F_{4, 12} = 6.19$, $p = 0.006$). The number of *S. schevyrewi* caught on baited sticky traps was significantly higher in 2011 than in 2010 ($F_{1, 12} = 32.34$, $p < 0.001$). The pattern of this between-year variation did not significantly differ between the two provinces ($F_{1, 12} = 1.61$, $p = 0.229$) or among the communities within provinces ($F_{4, 12} = 2.35$, $p = 0.113$).

In 2009, 2010 and 2011 in Saint-Adolphe, only one beetle was caught each year (Table 3) for a mean catch per trap of 0.33 ± 0.33 beetle (Table 4). The mean catch per trap was the highest in Maple Creek for all three years.

In all communities except La Salle, Otterburne and Saint-Adolphe, the average temperature for the duration of the baited sticky trap experiment was the lowest in 2010 (Table 5). The total precipitation during that same period was the highest in 2010. The general trend was for the total number of *S. schevyrewi* caught on baited sticky traps to decrease as the total precipitation increased (Fig. 5). That same trend was observed within Manitoba and Saskatchewan and within each year, except 2009.

Unfortunately, baited sticky traps deployed in Assiniboia and Estevan in 2009 were not changed on a weekly basis as was planned. To correct the situation, sampling activities in the two communities were moved to Swift Current and Weyburn, respectively, in 2010 and 2011. A consequence of the inconsistent removal of baited sticky traps in Assiniboia and Estevan was that the data could not be used to learn about the seasonal patterns of flight of *S. schevyrewi.* In Maple Creek in 2009, baited sticky traps were changed on a weekly basis from June 12 until October 23 except for two instances when traps were left for two and three weeks and another instance, from September 29 until October 6, when no baited sticky traps were deployed (Fig. 6). Except for a few other instances when traps were left on the poles for more than a week, dates on the x axis of Figs. 6–15 are dates of trap removal.

In Maple Creek, the first beetles were caught between June 12 and June 18 in 2009 (Fig. 6), between June 14 and June 22 in 2010 (Fig. 7) and between June 23 and June 29 in 2011 (Fig. 8). Peak catches occurred from July 30 to August 10 in 2009 (Fig. 6) and from August 24 to August 31 in both 2010 (Fig. 7) and 2011 (Fig. 8). The last beetles were caught between September 18 and September 29 in 2009 (Fig. 6), between August 31 and September 7 in 2010 (Fig. 7) and between September 28 and October 31 in 2011

(Fig. 8). The number of *S. schevyrewi* adults caught in other communities was lower and, as a result, the flight period graphs for these were not as well defined (Figs. 9–15). However, a pattern similar to that of Maple Creek in 2010 and 2011 was observed in most cases with reasonable catches: first catches occurred in June, peak catch was in late August or early September, and last catches were from mid to late September. Data for five instances of a single catch for the entire trapping season were not graphed. These instances (and trap collection date) were: 2009 in Saint-Adolphe (September 30), 2010, October 13 in Saint-Adolphe and Otterburne, and August 16 in Weyburn, and 2011 in Saint-Adolphe (September 29). In all these communities, traps were deployed no later than June 10 and trapping continued until at least October 25.

Adults of *S. schevyrewi* were never caught on the first week of trapping for all communities and all years. The earliest catch in the entire study was of one beetle caught between May 10 and May 18, 2010 in Carman (Fig. 14). During this period, the average temperature was 12.3°C (Environment Canada 2012). Of all the average temperatures for the eight instances when the period of first catches occurred before July, the one from Carman in 2010 was the lowest; the highest average temperature was 20.4°C and 50% of the other average temperatures were between 14.5°C and 18.0°C (Environment Canada 2012). However, the maximum temperature during the period of first catch in Carman in 2010 was 27°C which falls just under the mean maximum temperature for period of first catch in all locations and years, 28.1 ± 0.6°C (Environment Canada 2012). The total precipitation for the period during which the first beetle was caught in 2010 in Carman was 4.2 mm, which falls within the range of 50% of the values: 1.7 mm to 63.0 mm

(Environment Canada 2012). The lowest total precipitation during the period of first catch was 0 mm and the highest was 123.1 mm (Environment Canada 2012). In some cases (Figs. 7–11, 14–15), a small peak was noticeable after the first catch. This peak was followed by a decrease of catches, sometimes to zero, and then, by a higher peak in late summer.

Unbaited sticky traps

The total number of *S. schevyrewi* caught on unbaited sticky traps was much lower than from baited sticky traps (Tables 6–9). In 2009 in Saskatchewan, low catches could have been related to the irregular removal of unbaited sticky traps and the loss of some of them to vandalism. However, in 2010 and 2011, traps were changed every two weeks as was planned.

Only one *S. schevyrewi* was caught on *E. angustifolia* (Table 6). None were caught on unbaited sticky traps on *S. alba* (Table 7) and on *U. americana* showing Dutch elm disease symptoms (Table 8). However, of the 85 unbaited sticky traps stapled to *U. americana* in communities where Dutch elm disease occurs, only five were on *U. americana* showing symptoms of the disease and these five trees occurred in locations and years where *S. schevyrewi* were generally low on unbaited sticky traps (Table 8). The majority of *S. schevyrewi* caught on unbaited sticky traps was collected from traps on *U. americana* showing no symptoms of Dutch elm disease (Table 8) and on *U. pumila* (Table 9).

A single *S. schevyrewi* was collected on an unbaited sticky trap on a girdled *U.*

pumila in Weyburn in 2011 while five were caught on healthy *U. pumila* (Table 9). The girdled *U. pumila* were not paired with healthy *U. pumila,* and the Weyburn data were too sparse for further analyses. In Carman and Swift Current, the experiment was paired and catches were much higher (Table 10). In Carman, the mean catch per trap on girdled *U. pumila* was 25.60 ± 18.48 beetles and the mean catch per trap on control *U. pumila* was 0.40 ± 0.25 beetle. In Swift Current, the mean catch per trap on girdled *U. pumila* was 251.33 ± 207.22 beetles and the mean catch per trap on control *U. pumila* was 6.00 ± 3.00 beetles. Analysis of the $\log_{10}$ transformed data for both communities shows the same trend; total catches on girdled *U. pumila* were significantly higher than on control *U. pumila* ($F_{1,6} = 13.59$, $p = 0.010$). The variation between the two communities was not significant ($F_{1,6} = 4.76$, $p = 0.072$) and the pattern of higher catches on unbaited sticky traps on girdled *U. pumila* did not differ significantly between communities ($F_{1,6} = 0.04$, $p = 0.847$).

Trap logs

In the three years of the project, the trap log operations were carried out as planned in all Manitoba and Saskatchewan communities except for Assiniboia in 2009. In this community, some logs were deployed in July instead of June and only the August, October and winter batches were removed from the field on time.

Except for logs of *C. arborescens* and *E. angustifolia,* about 150 to 200 logs per species were dissected for *S. alba, U. americana* and *U. pumila* (Table 11). The preference of *S. schevyrewi* among these species was significantly different (likelihood ratio (LR) $\chi^2 = 189.67$, d.f. = 4, $p < 0.001$) and *U. pumila* was significantly preferred over the four other species (LR $\chi^2 = 189.67$, d.f. = 1, $p < 0.001$). *Ulmus pumila* logs were the only ones that were colonized which, for the purpose of this thesis, means that there was evidence that brood was or had been present at one point. Over all the *U. pumila* logs deployed in Assiniboia, Carman, Swift Current and Weyburn, 41% were colonized. La Salle, with no logs colonized, was the only community with less than one third of its *U. pumila* trap logs colonized over the three years of the project; however, only 16% *U. pumila* trap logs were colonized in Carman in 2010. The proportions of logs colonized and not colonized in Carman and Swift Current in 2010–2011 were subjected to contingency table analyses. Frequency of colonization did not differ significantly between the two communities (LR $\chi^2 = 3.68$, d.f. = 1, $p = 0.055$). Frequency of colonization differed between years (LR $\chi^2 = 4.85$, d.f. = 1, $p = 0.028$), and the effect of years differed between communities (LR $\chi^2 = 7.71$, d.f. = 1, $p = 0.005$).

The diameter of the *U. pumila* trap logs ranged from 6 cm to 28 cm with 10th, 50th and 90th percentiles being 10 cm, 18 cm and 26 cm, respectively (Fig. 16). The 10th percentile for diameter of colonized logs was 10.7 cm and for uncolonized logs was 10 cm. The 50th percentiles for diameter of colonized and uncolonized *U. pumila* trap logs were 18 cm and 20 cm, respectively. The 90th percentile for diameter of colonized logs was 23 cm and of uncolonized logs was 27 cm and the distributions of diameters of *U. pumila* trap logs that were colonized and not colonized were significantly different (maximum difference for pairs of groups = 0.263, $p = 0.003$, Kolmogorov-Smirnov two-sample test).

Dissection

Except for a single *S. schevyrewi* adult found in a single *U. pumila* trap log in July 2010 in Swift Current, and three larvae and 12 adults, found in an October 2011 log from the same community, the larval stage was the most represented in colonized *U. pumila* trap logs (Table 12). In general, for a single community and a single year, the number of *S. schevyrewi* at any stage found in *U. pumila* trap logs was lower in trap logs from batches brought back to the laboratory in the first half of the summer. This number was usually peaking in trap logs from batches brought back to the laboratory in the fall or winter. Data from Carman in 2010 follow an opposite trend and data from Swift Current in 2011 show a peak in August and lower numbers in July, September and October (Table 12). By pooling data for each community, the general trend can be observed for 2010 and 2011 (Figs 17–18). Although these numbers included both live and dead *S. schevyrewi* found, all adults found in winter trap logs were dead. Fluorescent powder was found on the single adult *S. schevyrewi* collected from a single winter *U. pumila* log covered in fluorescent powder in Swift Current in 2010–2011; this suggests that it was a parental generation beetle. In 2010, all adults, usually one or two, found in trap logs covered in fluorescent powder were marked. Except for adults found in October logs from Carman and August logs from Swift Current, the mean percentage of adults marked with the powder was always above 50% suggesting that most of the adults found were from a parental generation (Table 13).

Emergence cylinders

When the trap logs from the emergence cylinders were dissected, it was found that 89.7% of *S. schevyrewi* in the *U. pumila* logs brought back to the lab from July until November had completed their development and emerged (Table 14). Emergence from these trap logs was similar in Carman and Swift Current in 2010. Statistical analysis of the data for this particular year shows that there was a significant difference in frequency of emergence between the two communities (LR $\chi^2 = 6.24$, d.f. = 1, $p = 0.012$); however, this analysis was based on only two colonized logs from Carman and so, the results of the analysis are weak. As for 2011, there was no significant difference in emergence between the two communities (LR $\chi^2 = 0.87$, d.f. = 1, $p < 0.350$).

For trap logs that remained outside all winter, 13.8% *S. schevyrewi* completed their development in *U. pumila* logs and emerged (Table 14). Winter survival for *S. schevyrewi* was significantly lower than survival in the other months in the 2009–2010 interval in Assiniboia (LR $\chi^2 = 533.14$, d.f. = 1, $p < 0.001$), and in the 2010–2011 interval in Carman (LR $\chi^2 = 135.34$, d.f. = 1, $p < 0.001$) and Swift Current (LR $\chi^2 = 90.17$, d.f. = 1, $p < 0.001$). However, winter survival was significantly different between Carman and Swift Current in 2010 (LR $\chi^2 = 61.86$, d.f. = 1, $p < 0.001$). The coldest temperature recorded at the Winnipeg Richardson International Airport in the winters 2009–2010 and 2010–2011 was -34.1°C and -35.4°C, respectively (Environment Canada 2012). The coldest average temperature recorded by the six data-loggers in the pile of logs in the winter 2010–2011 was -29.8°C which is about 5°C warmer than the coldest temperature of that winter as recorded at the airport weather station. Although the average temperature for the months of December, January and February was less cold in 2009–2010 than in 2010–2011,

-14.3°C and -15.9°C, respectively (Environment Canada 2012), a greater proportion of *S. schevyrewi* survived in 2010–2011.

Development time

In 2011, in the whole log system, very few unmarked adults were found on logs at 15°C and 35°C (Table 15). Upon examination, between 15 and 20 entrance holes were found on one of the *U. pumila* logs at 15°C, but there were no maternal galleries. Both logs at 15°C were still wet at the end of the experiment. The logs that yielded no results at 25°C and 30°C were wet as well. The ones at these temperatures from which adults emerged as well as the ones at 20°C were dry. Logs at 35°C were also dry at the end of the experiment and one maternal gallery was found in one of them. Five galleries were found in the 20°C log from which two adults from a second generation were collected.

Many galleries were found in the three logs from which many adults emerged and were collected. In these three logs, emergence occurred for almost 200 days for the 20°C log (Fig. 19) and between 100 and 150 days for the 25°C and 30°C logs (Figs. 20–21). Many peaks can be observed on the graphs and as a result, it is difficult to determine the development duration. At 20°C, 25°C and 30°C, it takes approximately the same number of days for the first 1% of S. *schevyrewi* adults to emerge. However, for the first 5% *S. schevyrewi* adults to emerge, this number decreases as the temperature increases and decreases more from 20°C to 25°C than from 25°C to 30°C (Table 15).

TABLE 3. Total catches per trap of adult *Scolytus schevyrewi* (BEBB) caught on baited sticky traps in 2009, 2010, and 2011 and species of host trees within 50 m of these traps.

PROVINCE	COMMUNITY	TRAP	HOST TREES WITHIN[a]			BEBB COLLECTED			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL
MANITOBA	CARMAN	1	none	none	*Ulmus pumila*	N/A	1	0	1
		2	*Malus* sp.	none	none	N/A	2	28	30
		3	none	*Ulmus americana*	none	N/A	5	9	14
		TOTAL				N/A	8	37	45
	LA SALLE	1	none	none	none	0	0	N/A	0
		2	none	none	none	0	0	N/A	0
		3	none	none	none	0	0	N/A	0
		TOTAL				0	0	N/A	0
	OTTERBURNE	1	none	none	none	5	0	17	22
		2	none	none	none	4	0	4	8
		3	none	none	none	14	1	6	21
		TOTAL				23	1	27	51
	SAINT-ADOLPHE	1	none	none	none	1	1	0	2
		2	none	none	none	0	0	0	0
		3	none	none	none	0	0	1	1
		TOTAL				1	1	1	3
	TOTAL					24	10	65	99
SASKATCHEWAN	ASSINIBOIA	1	none	none	none	99	N/A	N/A	99
		2[b]	none	none	none	97	N/A	N/A	97
		3[b]	none	none	none	1	N/A	N/A	1
		4	*Salix* sp., *U. pumila*	none	none	1	N/A	N/A	1
		5[b]	none	none	none	26	N/A	N/A	26
		6	none	none	none	28	N/A	N/A	28
		TOTAL				252	N/A	N/A	252

TABLE 3 continued.

PROVINCE	COMMUNITY	TRAP	HOST TREES WITHIN[a]			BEBB COLLECTED			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL
SASKATCHEWAN	ESTEVAN	1[c]	?	?	?	1	N/A	N/A	1
		2[c]	?	?	?	6	N/A	N/A	6
		3[c]	?	?	?	0	N/A	N/A	0
		4[d]	none	none	none	64	N/A	N/A	64
		5	*U. americana*	none	none	37	N/A	N/A	37
		6	none	none	none	47	N/A	N/A	47
		TOTAL				155	N/A	N/A	155
	MAPLE CREEK	1	*U. americana*	*U. americana*	*U. americana*	61	13	62	136
		2	none	*U. americana*	*U. americana*	144	55	162	361
		3	none	none	none	25	12	57	94
		TOTAL				230	80	281	591
	SWIFT CURRENT	1	none	*U. pumila*	*U. pumila*	N/A	15	65	80
		2	none	none	*U. pumila*	N/A	5	13	18
		3	none	none	none	N/A	1	3	4
		TOTAL				N/A	21	81	102
	WEYBURN	1	none	none	none	N/A	1	4	5
		2	none	none	none	N/A	0	8	8
		3	none	none	none	N/A	0	8	8
		TOTAL				N/A	1	20	21
	TOTAL					637	102	382	1121
TOTAL						661	112	447	1220

[a] As in Negrón *et al.* 2005.

[b] Trap on pole with transformer.

[c] Within first month, traps 1, 2 and 3 changed to new locations (4, 5 and 6, respectively). Hosts not recorded.

[d] Trap on pole with street light.

TABLE 4. Mean catch per trap per community (± SE) of adult *Scolytus schevyrewi* caught on baited sticky traps.

PROVINCE	COMMUNITY	MEAN CATCH/TRAP ± SE		
		2009	2010	2011
MANITOBA	CARMAN	N/A	2.67 ± 1.20	12.33 ± 8.25
	LA SALLE	0.0	0.0	N/A
	OTTERBURNE	7.67 ± 3.18	0.33 ± 0.33	9.00 ± 4.04
	SAINT-ADOLPHE	0.33 ± 0.33	0.33 ± 0.33	0.33 ± 0.33
	OVERALL	2.67 ± 1.56	0.83 ± 0.42	7.22 ± 3.20
SASKATCHEWAN	ASSINIBOIA	42.00 ± 18.34	N/A	N/A
	ESTEVAN	25.83 ± 11.12	N/A	N/A
	MAPLE CREEK	76.67 ± 35.23	26.67 ± 14.17	93.67 ± 34.20
	SWIFT CURRENT	N/A	7.00 ± 4.16	27.00 ± 19.22
	WEYBURN	N/A	0.33 ± 0.33	6.67 ± 1.33
	OVERALL	42.47 ± 11.22	11.33 ± 5.81	42.44 ± 11.35

TABLE 5. Average temperature in all communities for the duration of the baited sticky trap experiment (Environment Canada 2012).

PROVINCE	COMMUNITY	AVERAGE TEMPERATURE (°C)		
		2009	2010	2011
MANITOBA	CARMAN	N/A	12.9	16.3
	LA SALLE[a]	12.3	14.0	N/A
	OTTERBURNE[a]	11.7	13.2	13.2
	SAINT-ADOLPHE[a]	11.7	13.2	13.2
SASKATCHEWAN	ASSINIBOIA	14.2	N/A	N/A
	ESTEVAN	16.9	N/A	N/A
	MAPLE CREEK	13.7	12.5	15.2
	SWIFT CURRENT	N/A	12.4	14.8
	WEYBURN	N/A	15.4	18.5

[a] Carman weather data were used for these communities. However, the trapping period varied from one community to the other, explaining the different average temperatures in these three communities and Carman.

TABLE 6. Total catches per trap of adult *Scolytus schevyrewi* (BEBB) caught on unbaited sticky traps on *Elaeagnus angustifolia* in 2009, 2010, and 2011 in Saskatchewan communities and species of host trees within 50 m of these traps.

COMMUNITY	TRAP	OTHER HOST TREES WITHIN[a]			BEBB COLLECTED			
		≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL
ESTEVAN	1	*Elaeagnus angustifolia, Ulmus americana*	none	*E. angustifolia, U americana*	0	N/A	N/A	0
	2	*E. angustifolia*	none	*E. angustifolia, U americana*	0	N/A	N/A	0
	3	*E. angustifolia*	none	*E. angustifolia, U americana*	0	N/A	N/A	0
	TOTAL				0	N/A	N/A	0
SWIFT CURRENT	1	none	*U. americana*	*U. americana*	N/A	0	0	0
	2	none	none	*Salix alba*	N/A	0	0	0
	3	none	none	*S. alba*	N/A	0	0	0
	4	none	none	*S. alba*	N/A	0	0	0
	5	none	none	*S. alba*	N/A	0	0	0
	TOTAL				N/A	0	0	0
WEYBURN	1	*Caragana arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	N/A	0	0	0
	2	*C. arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	N/A	0	0	0
	3	*C. arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	N/A	0	0	0
	4	*C. arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	N/A	0	0	0
	5	*C. arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	N/A	1	0	1
	TOTAL				N/A	1	0	1
TOTAL					0	1	0	1

[a] As in Negrón *et al.* 2005.

TABLE 7. Total catches per trap of adult *Scolytus schevyrewi* (BEBB) caught on unbaited sticky traps on *Salix alba* in 2009, 2010, and 2011 and species of host trees within 50 m of these traps.

PROVINCE	COMMUNITY	TRAP	OTHER HOST TREES WITHIN[a]			BEBB COLLECTED			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL
MANITOBA	CARMAN	1	*Caragana arborescens, Salix alba*	*C. arborescens, S. alba*	*C. arborescens, S. alba*	N/A	0	0	0
		2	*C. arborescens, S. alba*	*C. arborescens, S. alba*	*C. arborescens, S. alba*	N/A	0	0	0
		3	*C. arborescens, S. alba*	*C. arborescens, S. alba*	*C. arborescens, S. alba*	N/A	0	0	0
		4	*C. arborescens, S. alba*	*C. arborescens, S. alba*	*C. arborescens, S. alba*	N/A	0	0	0
		5	*C. arborescens, S. alba*	*C. arborescens, S. alba*	*C. arborescens, S. alba*	N/A	0	0	0
		TOTAL				N/A	0	0	0
	LA SALLE	1	*S. alba*	*S. alba*	*S. alba*	0	N/A	N/A	0
		2	*S. alba*	*S. alba*	*S. alba*	0	N/A	N/A	0
		3	*S. alba*	*S. alba*	*S. alba*	0	N/A	N/A	0
		4	*S. alba*	*S. alba*	*S. alba*	0	N/A	N/A	0
		5	*S. alba*	*S. alba*	*S. alba*	0	N/A	N/A	0
		TOTAL				0	N/A	N/A	0
	TOTAL					0	0	0	0
SASKATCHEWAN	ESTEVAN	1[b]	?	?	?	0	N/A	N/A	0
		2	none	*Ulmus americana*	none	0	N/A	N/A	0
		TOTAL				0	N/A	N/A	0
	TOTAL					0	N/A	N/A	0
TOTAL						0	0	0	0

[a] As in Negrón *et al.* 2005.

[b] Within first month, trap 1 changed to new location (2). Hosts not recorded.

TABLE 8. Total catches per trap of adult *Scolytus schevyrewi* (BEBB) caught on unbaited sticky traps on *Ulmus americana* in 2009, 2010, and 2011 and species of host trees within 50 m of these traps.

PROVINCE	COMMUNITY	TRAP	OTHER HOST TREES WITHIN[a]			BEBB COLLECTED			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL
MANITOBA	CARMAN	1[b]	*Ulmus americana*	*U. americana*	*U. americana*	N/A	0	0	0
		2[b]	*U. americana*	*U. americana*	*U. americana*	N/A	0	2	2
		3[b]	*U. americana*	*U. americana*	*U. americana*	N/A	0	0	0
		4[b]	*U. americana*	*U. americana*	*U. americana*	N/A	0	0	0
		5[b]	*U. americana*	*U. americana*	*U. americana*	N/A	0	0	0
		6[bc]	*U. americana*	*U. americana*	*U. americana*	N/A	0	N/A	0
		7[b]	*U. americana*	*U. americana*	*U. americana*	N/A	0	0	0
		8[b]	*U. americana*	*U. americana*	*U. americana*	N/A	0	0	0
		9[b]	*U. americana*	*U. americana*	*U. americana*	N/A	0	0	0
		10[b]	*U. americana*	*U. americana*	*U. americana*	N/A	0	0	0
		11[b]	*U. americana*	*U. americana*	*U. americana*	N/A	N/A	2	2
		TOTAL				N/A	0	4	4
	LA SALLE	1[b]	*U. americana*	*U. americana*	*U. americana*	0	N/A	N/A	0
		2[b]	*U. americana*	*U. americana*	*U. americana*	0	N/A	N/A	0
		3[b]	*U. americana*	*U. americana*	*U. americana*	0	N/A	N/A	0
		4[b]	*U. americana*	*U. americana*	*U. americana*	0	N/A	N/A	0
		5[b]	*U. americana*	*U. americana*	*U. americana*	0	N/A	N/A	0
		6[b]	*U. americana*	*U. americana*	*U. americana*	0	N/A	N/A	0
		7[b]	*U. americana*	*U. americana*	*U. americana*	1	N/A	N/A	1
		8[b]	*U. americana*	*U. americana*	*U. americana*	0	N/A	N/A	0
		9[b]	*U. americana*	*U. americana*	*U. americana*	0	N/A	N/A	0
		10[b]	*U. americana*	*U. americana*	*U. americana*	0	N/A	N/A	0
		11[bc]	*U. americana*	*U. americana*	*U. americana*	0	N/A	N/A	0
		12[bc]	*U. americana*	*U. americana*	*U. americana*	0	N/A	N/A	0
		13[bc]	*U. americana*	*U. americana*	*U. americana*	0	N/A	N/A	0
		14[bc]	*U. americana*	*U. americana*	*U. americana*	0	N/A	N/A	0
		TOTAL				1	N/A	N/A	1
	TOTAL					1	0	4	5

TABLE 8 continued.

PROVINCE	COMMUNITY	TRAP	OTHER HOST TREES WITHIN[a]			BEBB COLLECTED			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL
SASKATCHEWAN	ESTEVAN	1[d]	?	?	?	0	N/A	N/A	0
		2[d]	?	?	?	0	N/A	N/A	0
		3[d]	?	?	?	0	N/A	N/A	0
		4[d]	?	?	?	0	N/A	N/A	0
		5[d]	?	?	?	0	N/A	N/A	0
		6[d]	?	?	?	0	N/A	N/A	0
		7[d]	?	?	?	0	N/A	N/A	0
		8[d]	?	?	?	0	N/A	N/A	0
		9[d]	?	?	?	0	N/A	N/A	0
		10[d]	?	?	?	0	N/A	N/A	0
		11[d]	?	?	?	0	N/A	N/A	0
		12[d]	?	?	?	0	N/A	N/A	0
		13[d]	?	?	?	0	N/A	N/A	0
		14[e]	?	?	?	0	N/A	N/A	0
		15[e]	?	?	?	0	N/A	N/A	0
		16[e]	?	?	?	0	N/A	N/A	0
		17[e]	?	?	?	2	N/A	N/A	2
		18[e]	?	?	?	0	N/A	N/A	0
		19[e]	?	?	?	0	N/A	N/A	0
		20[e]	?	?	?	0	N/A	N/A	0
		21[e]	?	?	?	0	N/A	N/A	0
		22[e]	?	?	?	1	N/A	N/A	1
		23[e]	?	?	?	0	N/A	N/A	0
		24[e]	?	?	?	0	N/A	N/A	0
		25[e]	?	?	?	0	N/A	N/A	0
		26[e]	?	?	?	0	N/A	N/A	0
		27[e]	?	?	?	0	N/A	N/A	0
		28[e]	?	?	?	0	N/A	N/A	0

TABLE 8 continued.

PROVINCE	COMMUNITY	TRAP	OTHER HOST TREES WITHIN[a]			BEBB COLLECTED			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL
SASKATCHEWAN	ESTEVAN	29[e]	?	?	?	0	N/A	N/A	0
		30[e]	?	?	?	0	N/A	N/A	0
		31[e]	?	?	?	0	N/A	N/A	0
		TOTAL				3	N/A	N/A	3
	SWIFT CURRENT	1	*U. americana*	*U. americana, Ulmus pumila*	*U. americana*	N/A	0	0	0
		2	*U. americana*	*U. americana, U. pumila*	*U. americana*	N/A	0	0	0
		3	*U. americana*	*U. americana, U. pumila*	*U. americana*	N/A	0	0	0
		4	*U. americana, U. pumila*	*U. americana*	*U. americana*	N/A	0	0	0
		5	*U. americana*	*U. americana, U. pumila*	*U. americana*	N/A	0	0	0
		6	*U. americana*	*U. americana, U. pumila*	*U. americana*	N/A	0	0	0
		7	*U. americana*	*U. americana, U. pumila*	*U. americana*	N/A	0	0	0
		8	*U. americana*	*U. americana, U. pumila*	*U. americana*	N/A	0	0	0
		9	*U. americana*	*U. americana*	*U. americana, U. pumila*	N/A	0	0	0
		10	*U. americana*	*U. americana*	*U. americana, U. pumila*	N/A	0	0	0
		TOTAL				N/A	0	0	0
	WEYBURN	1	*Caragana arborescens, U. americana*	*C. arborescens, U. americana*	*C. arborescens, U. americana*	N/A	0	1	1
		2	*C. arborescens, U. americana*	*C. arborescens, U. americana*	*C. arborescens, U. americana*	N/A	0	0	0
		3	*C. arborescens, U. americana*	*C. arborescens, U. americana*	*C. arborescens, U. americana*	N/A	0	0	0
		4	*C. arborescens, U. americana*	*C. arborescens, U. americana*	*C. arborescens, U. americana*	N/A	2	0	2
		5	*C. arborescens, U. americana*	*C. arborescens, U. americana*	*C. arborescens, U. americana*	N/A	0	0	0
		6	*U. americana*	*U. americana*	*C. arborescens, U. americana*	N/A	0	0	0

TABLE 8 continued.

PROVINCE	COMMUNITY	TRAP	OTHER HOST TREES WITHIN[a]			BEBB COLLECTED			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL
SASKATCHEWAN	WEYBURN	7	*U. americana*	*U. americana*	*C. arborescens, U. americana*	N/A	0	0	0
		8	*U. americana*	*U. americana*	*C. arborescens, U. americana*	N/A	0	0	0
		9	*U. americana*	*U. americana*	*C. arborescens, U. americana*	N/A	0	0	0
		10	*U. americana*	*U. americana*	*C. arborescens, U. americana*	N/A	0	0	0
		TOTAL				N/A	2	1	3
	TOTAL					3	2	1	6
TOTAL						4	2	5	11

[a] As in Negrón *et al.* 2005.

[b] In riparian forest.

[c] Infected with Dutch elm disease.

[d] Within first month, traps 1 to 13 changed to new locations. Hosts not recorded.

[e] Hosts not recorded.

TABLE 9. Total catches per trap of adult *Scolytus schevyrewi* (BEBB) caught on unbaited sticky traps on *Ulmus pumila* in 2009, 2010, and 2011 and species of host trees within 50 m of these traps.

PROVINCE	COMMUNITY	TRAP	OTHER HOST TREES WITHIN[a]			BEBB COLLECTED			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL
MANITOBA	CARMAN	1	*Ulmus pumila*	*U. pumila*	*U. pumila*	N/A	0	0	0
		2	*U. pumila*	*U. pumila*	*U. pumila*	N/A	0	1	1
		3	*U. pumila*	*U. pumila*	*U. pumila*	N/A	0	0	0
		4	*U. pumila*	*U. pumila*	*U. pumila*	N/A	0	0	0
		5	*U. pumila*	*U. pumila*	*U. pumila*	N/A	0	0	0
		TOTAL				N/A	0	1	1
	LA SALLE	1	*U. pumila*	*U. pumila*	*U. pumila*	0	N/A	N/A	0
		2	*U. pumila*	*U. pumila*	*U. pumila*	0	N/A	N/A	0
		3	*U. pumila*	*U. pumila*	*U. pumila*	0	N/A	N/A	0
		4	*U. pumila*	*U. pumila*	*U. pumila*	0	N/A	N/A	0
		5	*U. pumila*	*U. pumila*	*U. pumila*	0	N/A	N/A	0
		TOTAL				0	N/A	N/A	0
	TOTAL					0	0	1	1
SASKATCHEWAN	ESTEVAN	1[b]	?	?	?	0	N/A	N/A	0
		2[b]	?	?	?	0	N/A	N/A	0
		3[b]	?	?	?	0	N/A	N/A	0
		4[b]	?	?	?	0	N/A	N/A	0
		5[b]	?	?	?	0	N/A	N/A	0
		6[c]	?	?	?	0	N/A	N/A	0
		7[c]	?	?	?	2	N/A	N/A	2
		8[c]	?	?	?	0	N/A	N/A	0
		9[c]	?	?	?	0	N/A	N/A	0
		10[c]	?	?	?	0	N/A	N/A	0
		11[c]	?	?	?	0	N/A	N/A	0
		12[c]	?	?	?	0	N/A	N/A	0
		13[c]	?	?	?	0	N/A	N/A	0
		14[c]	?	?	?	0	N/A	N/A	0
		15[c]	?	?	?	1	N/A	N/A	1
		TOTAL				3	N/A	N/A	3

TABLE 9 continued.

PROVINCE	COMMUNITY	TRAP	OTHER HOST TREES WITHIN[a]			BEBB COLLECTED			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL
SASKATCHEWAN	SWIFT CURRENT	1	*U. pumila*	*Ulmus americana, U. pumila*	*U. americana, U. pumila*	N/A	0	0	0
		2	*U. pumila*	*U. pumila*	*U. americana, U. pumila*	N/A	0	0	0
		3	*U. pumila*	*U. pumila*	*U. pumila*	N/A	2	0	2
		4	*U. pumila*	*U. pumila*	*U. pumila*	N/A	0	0	0
		5	*U. americana*	*U. americana*	*U. americana*	N/A	0	0	0
		TOTAL				N/A	2	0	2
	WEYBURN	1	*Malus* sp., *U. pumila*	*U. americana, U. pumila*	*U. americana, U. pumila*	N/A	0	2	2
		2	*Malus* sp., *U. pumila*	*U. americana, U. pumila*	*U. americana, U. pumila*	N/A	1	2	3
		3	*Malus* sp., *U. pumila*	*U. pumila*	*U. americana, U. pumila*	N/A	0	1	1
		4	*Malus* sp., *U. pumila*	*U. pumila*	*U. americana, U. pumila*	N/A	0	0	0
		5	*Malus* sp., *U. pumila*	*U. pumila*	*U. americana, U. pumila*	N/A	0	0	0
		6[d]	*Caragana arborescens, U. pumila*	*C. arborescens, U. pumila*	*C. arborescens, U. pumila*	N/A	N/A	0	0
		7[d]	*C. arborescens, U. pumila*	*C. arborescens, U. pumila*	*C. arborescens, U. pumila*	N/A	N/A	0	0
		8[d]	*C. arborescens, U. pumila*	*C. arborescens, U. pumila*	*C. arborescens, U. pumila*	N/A	N/A	1	1
		9[d]	*C. arborescens, U. pumila*	*C. arborescens, U. pumila*	*C. arborescens, U. pumila*	N/A	N/A	0	0
		TOTAL				N/A	1	6	7
	TOTAL					3	3	6	12
TOTAL						3	3	7	13

[a] As in Negrón *et al.* 2005.

[b] Within first month, traps 1 to 5 changed to new locations. Hosts not recorded.

[c] Hosts not recorded.

[d] Girdled, but not paired with healthy *U. pumila.*

TABLE 10. Total catches per trap of adult *Scolytus schevyrewi* (BEBB) caught on unbaited sticky traps on healthy *Ulmus pumila* paired with girdled *U. pumila* in 2011 and species of host trees within 50 m of these traps.

PROVINCE	COMMUNITY	PAIR[a]	OTHER HOST TREES WITHIN[b]			BEBB COLLECTED	
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	HEALTHY	GIRDLED
MANITOBA	CARMAN	1	*Ulmus pumila*	*U. pumila*	girdled *U. pumila*, *U. pumila*	1	13
		2	*U. pumila*	*U. pumila*	girdled *U. pumila*, *U. pumila*	0	99
		3	*Salix alba*, *U. pumila*	*S. alba*, *U. pumila*	*S. alba*, girdled *U. pumila*, *U. pumila*	1	2
		4	*S. alba*, *U. pumila*	*S. alba*, *U. pumila*	*S. alba*, girdled *U. pumila*, *U. pumila*	0	11
		5	*S. alba*, *U. pumila*	*S. alba*, *U. pumila*	*S. alba*, girdled *U. pumila*, *U. pumila*	0	3
		TOTAL				2	128
SASKATCHEWAN	SWIFT CURRENT	1	*Elaeagnus angustifolia*, *Prunus* sp.	*E. angustifolia*, *Prunus* spp., *Ulmus americana*, *U. pumila*	*E. angustifolia*, *Prunus* spp., *U. americana*, *U. pumila*	12	663
		2	*U. americana*	*E. angustifolia*, *Prunus* spp., *U. americana*, *U. pumila*	*E. angustifolia*, *Prunus* spp., *S. alba*, *U. americana*, *U. pumila*	3	87
		3	none	*U. americana*, *U. pumila*	*S. alba*, *Prunus* spp., *U. americana*, *U. pumila*	3	4
		TOTAL				18	754
TOTAL						20	882

[a] Trees from one pair are separated by 20 m.

[b] As in Negrón *et al.* 2005.

TABLE 11. Frequency with which dissected trap logs of five tree species were colonized by *Scolytus schevyrewi.* Data include trap logs that were dissected after having been removed from emergence cylinders.

TREE SPECIES	YEAR[a]	MANITOBA					SASKATCHEWAN							AVERAGE (%)
		CARMAN		LA SALLE		AVERAGE (%)	ASSINIBOIA		SWIFT CURRENT		WEYBURN		AVERAGE (%)	
		COLONIZED (%)	*n*	COLONIZED (%)	*n*		COLONIZED (%)	*n*	COLONIZED (%)	*n*	COLONIZED (%)	*n*		
Caragana arborescens		N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	10	N/A	N/A	0	0
Elaeagnus angustifolia		N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	54	N/A	N/A	0	0
Salix alba		0	119	0	24	0	0	23	N/A	N/A	N/A	N/A	0	0
Ulmus americana		0	66	0	24	0	0	7	0	79	N/A	N/A	0	0
Ulmus pumila	2009	N/A	N/A	0	22	0	53	30	N/A	N/A	N/A	N/A	53	27
	2010	16	51	N/A	N/A	16	N/A	N/A	51	51	33	6	28	22
	2011	54	28	N/A	N/A	54	N/A	N/A	46	24	N/A	N/A	46	50
	AVERAGE	35		0		23	53		48		33		42	33

[a] For species of host trees other than *U. pumila,* the three years have been pooled.

TABLE 12. Mean percentage of *Scolytus schevyrewi* (BEBB) (± SE) at different stages and total numbers of *S. schevyrewi* and galleries found in dissected *Ulmus pumila* trap logs in relation to the trap log removal date.

YEAR	COMMUNITY	MONTH	MEAN (±SE) PERCENTAGE OF BEBB			TOTAL NUMBER		NUMBER OF LOGS		
			LARVA	PUPA	ADULT	BEBB	GALLERIES	WITH BEBB	WITH GALLERIES	DISSECTED
2009	ASSINIBOIA	AUGUST	N/A	N/A	N/A	0	2	0	1	3
		OCTOBER	98.9	0.0	1.1	178	11	1	2	3
		WINTER	83.6 ± 4.2	3.8 ± 1.0	12.6 ± 3.3	1028	63	4	5	10
2010	CARMAN	AUGUST	88.6 ± 9.6	11.4 ± 9.6	0.0 ± 0.0	114	4	2	2	3
		NOVEMBER	93.1 ± 6.9	0.0 ± 0.0	6.9 ± 6.9	56	2	2	2	15
	SWIFT CURRENT	JULY	0.0	0.0	100.0	1	6	1	1	4
		AUGUST	94.6 ± 4.5	0.0 ± 0.0	5.4 ± 4.5	111	13	3	3	4
		SEPTEMBER	97.3	1.4	1.4	369	16	1	1	4
		OCTOBER	99.1 ± 0.3	0.1 ± 0.1	0.7 ± 0.4	2261	37	3	3	4
		WINTER	94.4 ± 3.3	0.3 ± 0.3	5.3 ± 3.4	955	37	7	7	12
	WEYBURN	OCTOBER	95.2 ± 1.2	0.5 ± 0.5	4.4 ± 1.6	326	14	2	2	6
2011	CARMAN	JULY	N/A	N/A	N/A	0	3	0	2	4
		AUGUST	55.5 ± 14.6	18.8 ± 0.7	25.6 ± 15.3	186	5	2	2	4
		SEPTEMBER	88.6 ± 9.7	9.8 ± 9.2	1.6 ± 0.5	324	5	2	2	4
		OCTOBER	98.6 ± 0.8	0.8 ± 0.5	0.6 ± 0.3	1240	18	3	3	4
	SWIFT CURRENT	JULY	100.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	33	10	2	2	3
		AUGUST	47.1 ± 33.6	20.6 ± 8.2	32.3 ± 25.4	197	10	2	2	3
		SEPTEMBER	69.9 ± 19.9	1.5 ± 1.5	28.7 ± 21.3	72	16	2	2	3
		OCTOBER	44.5 ± 26.9	5.9 ± 5.9	49.6 ± 21.0	31	9	2	2	3

TABLE 13. Mean percentage (± SE) of adult *Scolytus schevyrewi* marked with fluorescent powder collected from dissected *Ulmus pumila* trap logs from Carman and Swift Current in relation to removal date.

COMMUNITY	MONTH	BEBB	
		MARKED (±SE) (%)	TOTAL
CARMAN	AUGUST	85.3 ± 14.7	24
	SEPTEMBER	66.7 ± 33.3	5
	OCTOBER	7.1 ± 7.1	9
SWIFT CURRENT	AUGUST	16.1 ± 16.1	32
	SEPTEMBER	100.0	2
	OCTOBER	90.9 ± 9.1	15

TABLE 14. Percentage of adult *Scolytus schevyrewi* (BEBB) that emerged from *Ulmus pumila* trap logs in emergence cylinders.

COMMUNITY	SUMMER			WINTER		
	YEAR	BEBB		INTERVAL	BEBB	
		EMERGED (%)	TOTAL		EMERGED (%)	TOTAL
ASSINIBOIA	2009	97.6	125	2009–2010	3.9	768
	2010	N/A	N/A			
CARMAN	2010	100.0	60	2010–2011	15.7	102
	2011	80.2	431			
SWIFT CURRENT	2010	94.7	720	2010–2011	64.4	146
	2011	83.8	136			

TABLE 15. Number of days it took for the first 1% and 5% *Scolytus schevyrewi* (BEBB) adults to emerge from *Ulmus pumila* logs at different temperature regimes and total numbers that emerged from these logs.

TEMPERATURE (°C)	LOG	DAYS TO EMERGENCE		BEBB
		1% BEBB	5% BEBB	
15	1	N/A	N/A	2
	2	N/A	N/A	2
20	1	N/A	N/A	2
	2	48	95	159
25	1	48	65	581
	2	N/A	N/A	0
30	1	52	56	247
	2	N/A	N/A	0
35	1	N/A	N/A	2
	2	N/A	N/A	0

FIG. 5. Total precipitation for the duration of baited sticky trapping in 2009, 2010, and 2011 for all communities where an Environment Canada weather station was available: Carman, MB, and Maple Creek, Swift Current and Weyburn, SK (Environment Canada 2012), and total numbers of *Scolytus schevyrewi* (BEBB) caught on the three baited sticky traps in each community.

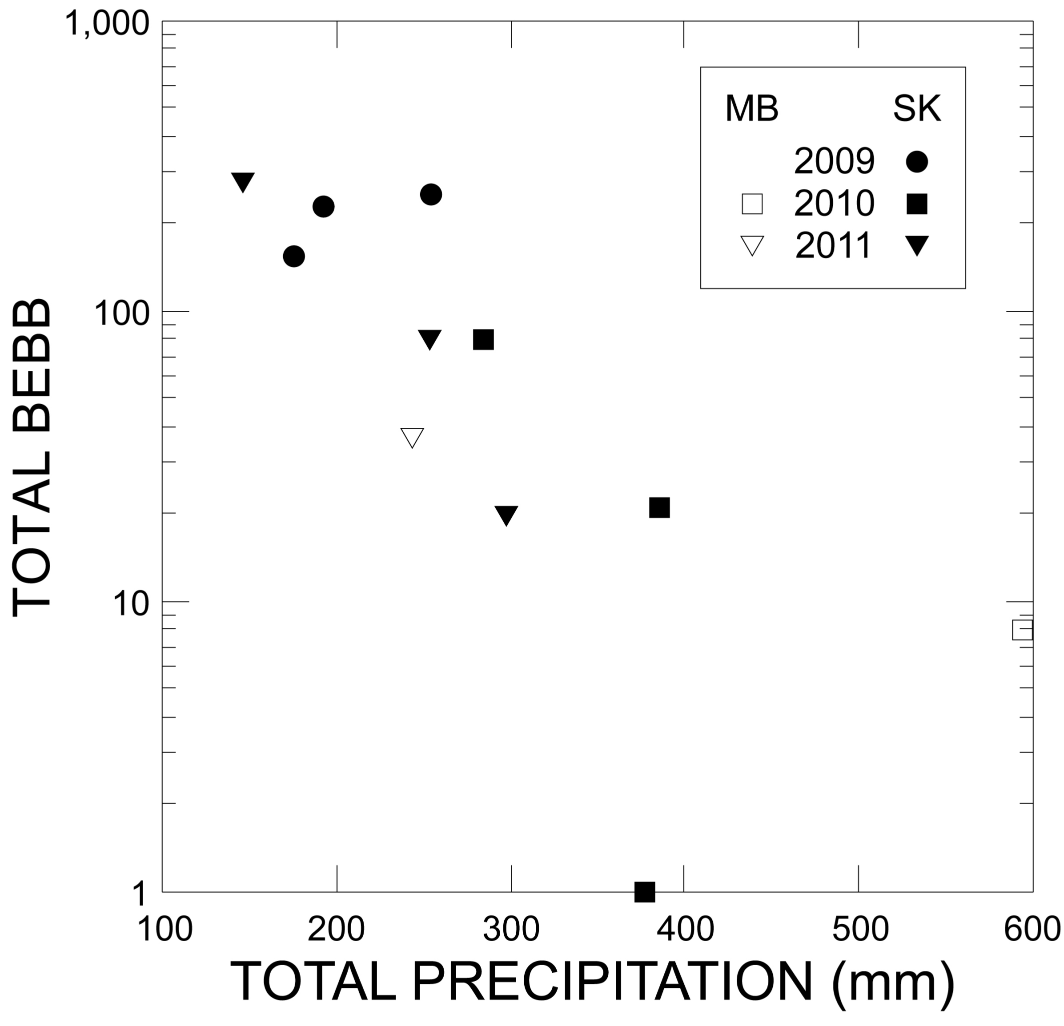


FIG. 6. Catches (mean ± SE) of adult *Scolytus schevyrewi* on baited sticky traps in Maple Creek, SK in 2009. Dates are those of trap collection; trapping began on June 4.

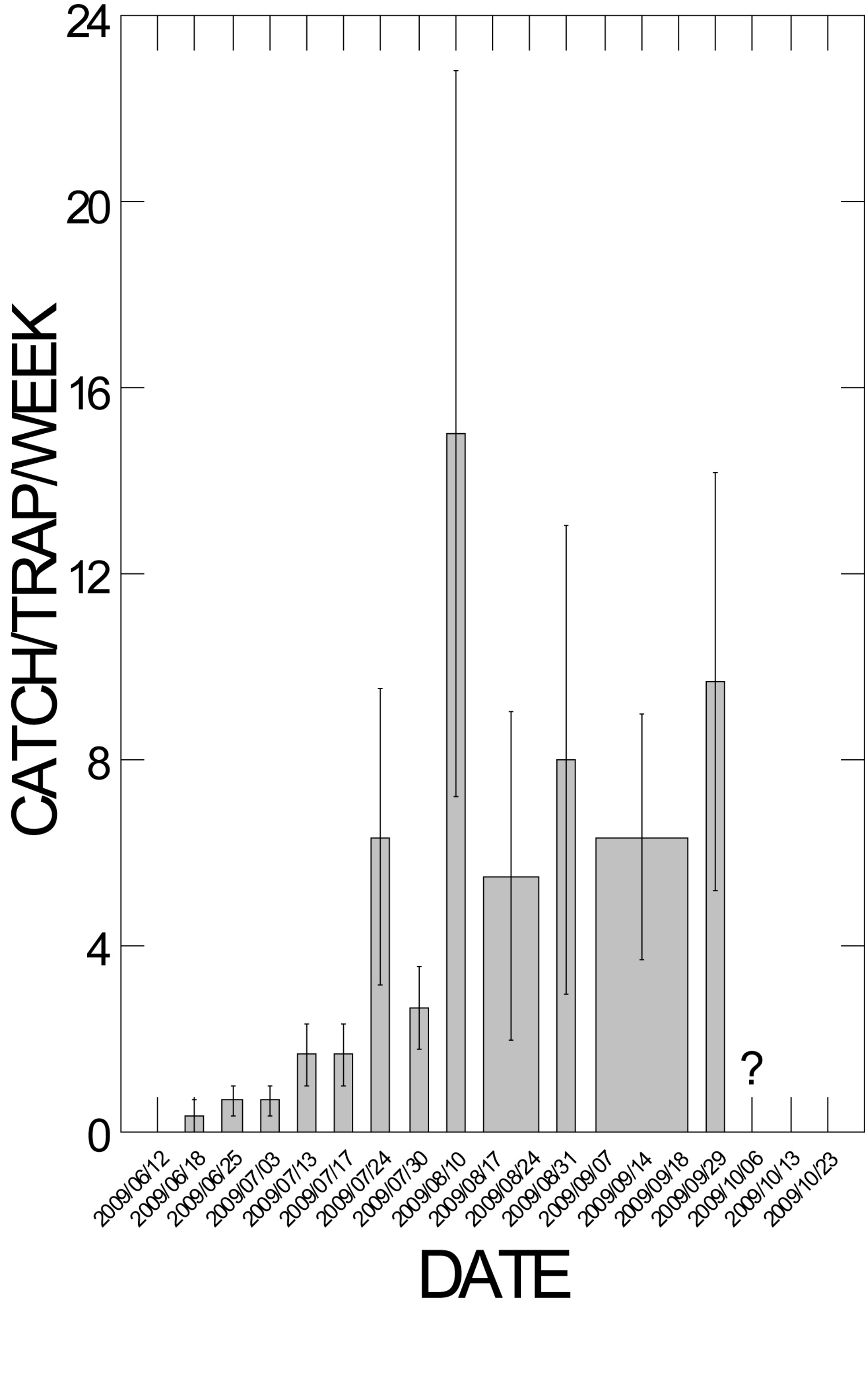


FIG. 7. Catches (mean ± SE) of adult *Scolytus schevyrewi* on baited sticky traps in Maple Creek, SK in 2010. Dates are those of trap collection; trapping began on May 26.

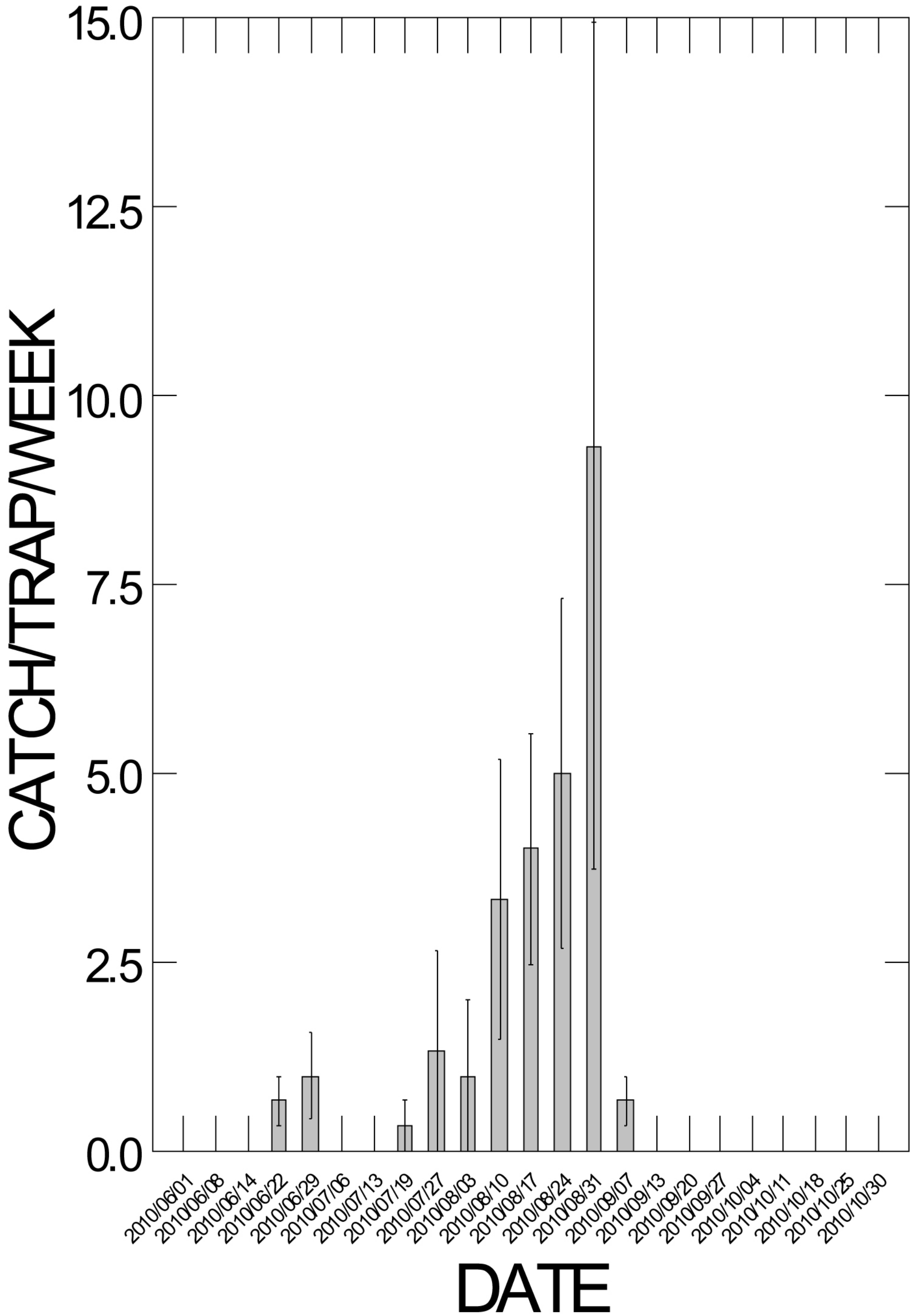


FIG. 8. Catches (mean ± SE) of adult *Scolytus schevyrewi* on baited sticky traps in Maple Creek, SK in 2011. Dates are those of trap collection; trapping began on June 2.

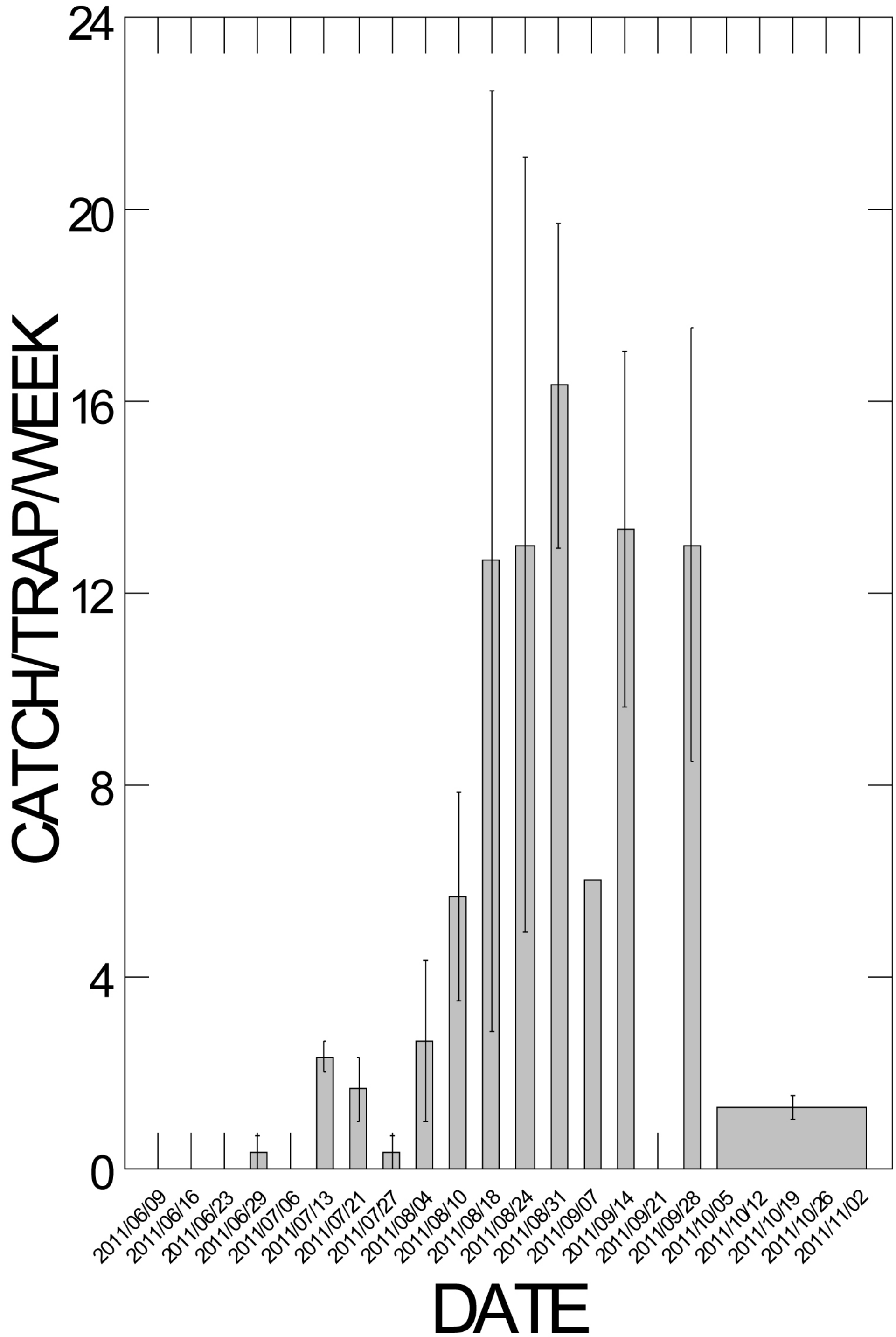


FIG. 9. Catches (mean ± SE) of adult *Scolytus schevyrewi* on baited sticky traps in Swift Current, SK in 2010. Dates are those of trap collection; trapping began on May 31.

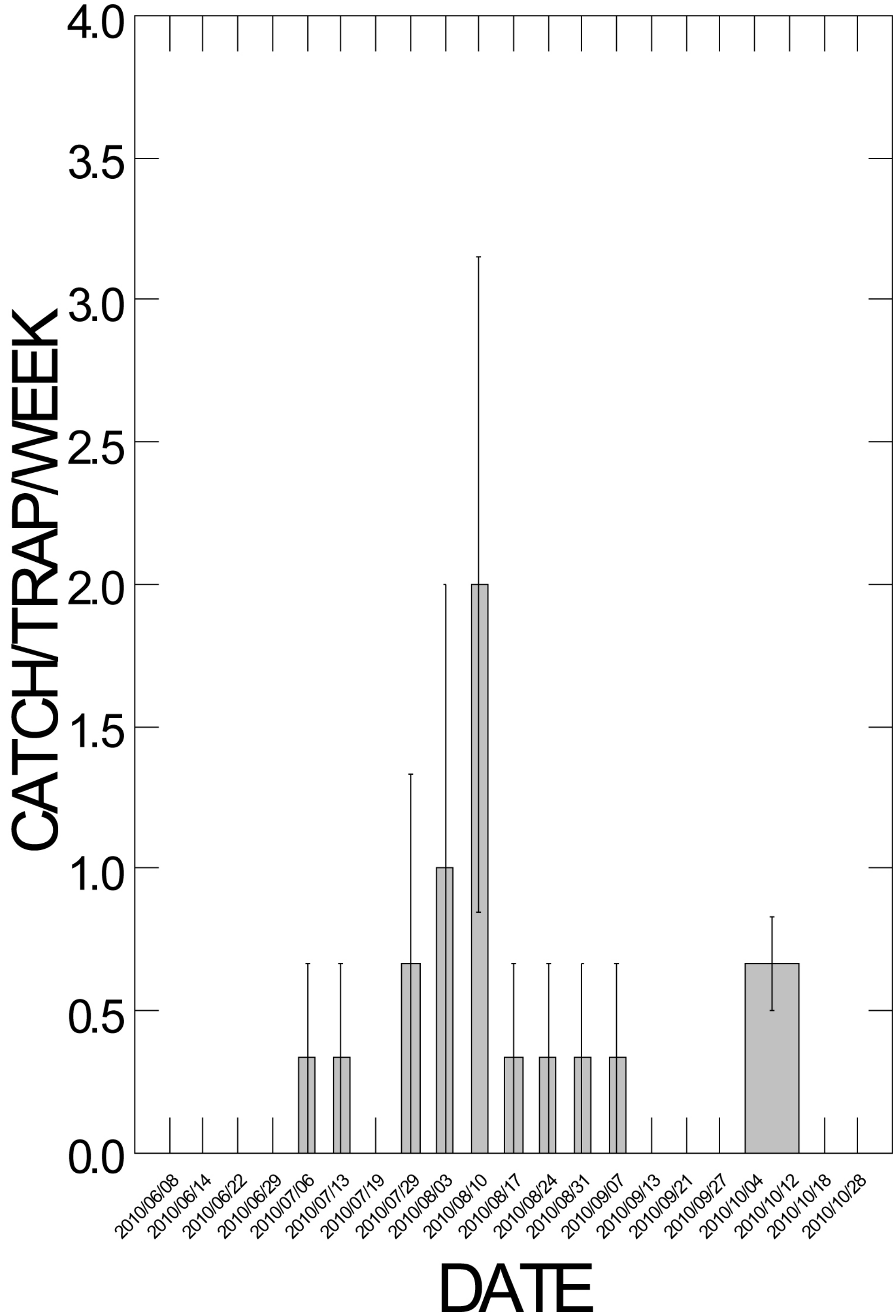


FIG. 10. Catches (mean ± SE) of adult *Scolytus schevyrewi* on baited sticky traps in Swift Current, SK in 2011. Dates are those of trap collection; trapping began on June 3.

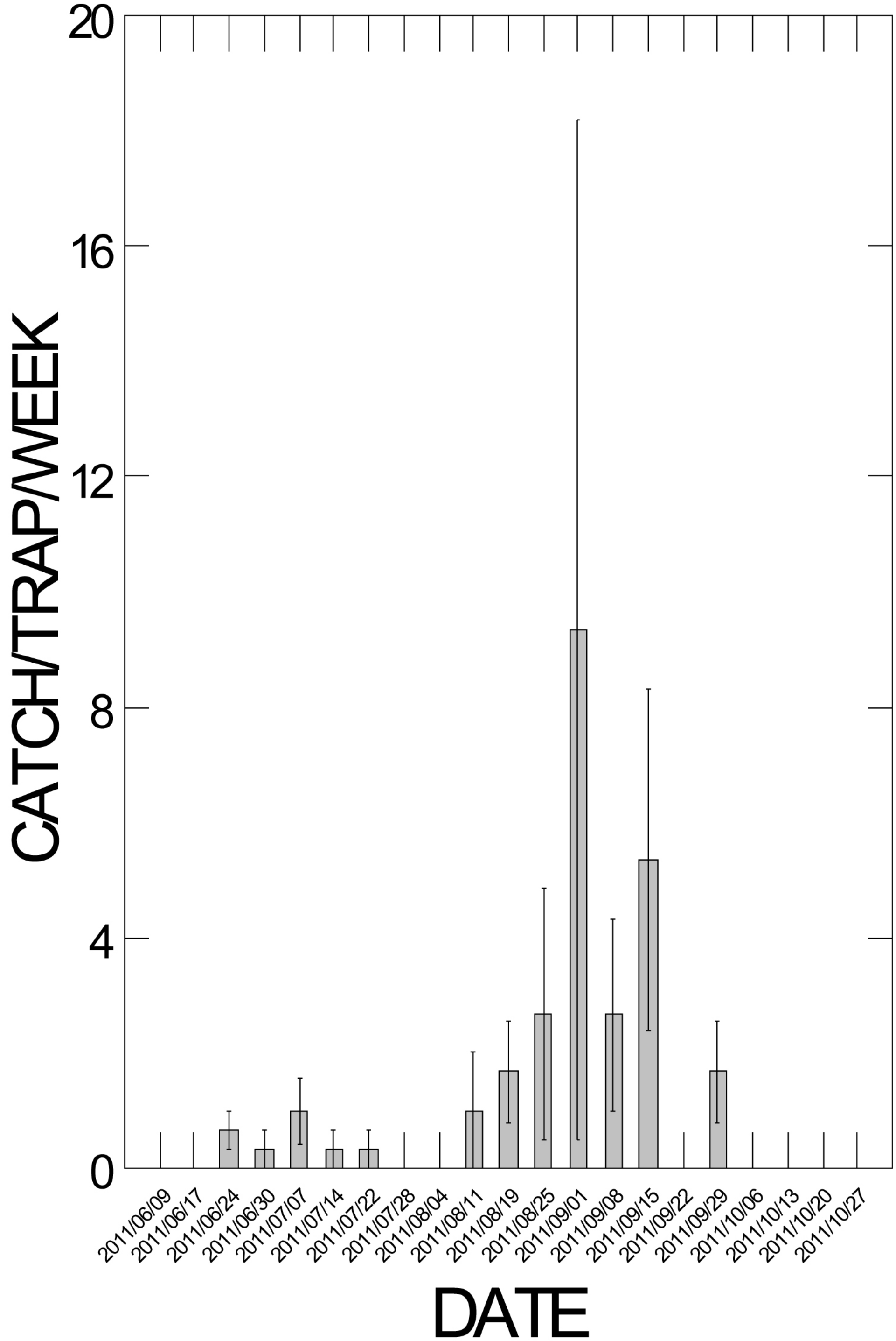


FIG. 11. Catches (mean ± SE) of adult *Scolytus schevyrewi* on baited sticky traps in Weyburn, SK in 2011. Dates are those of trap collection; trapping began on June 13.

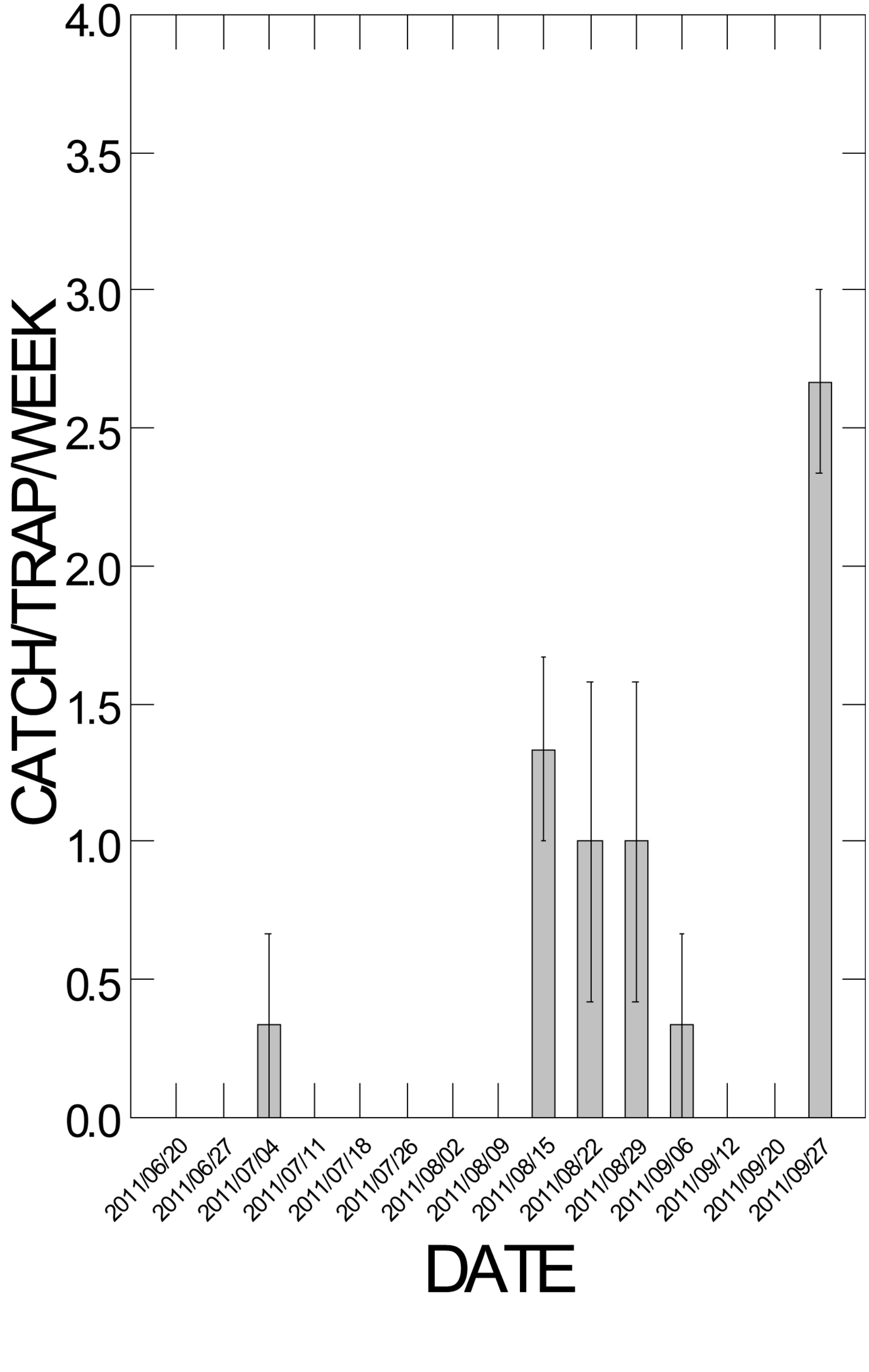


FIG. 12. Catches (mean ± SE) of adult *Scolytus schevyrewi* on baited sticky traps in Otterburne, MB in 2009. Dates are those of trap collection; trapping began on June 3.

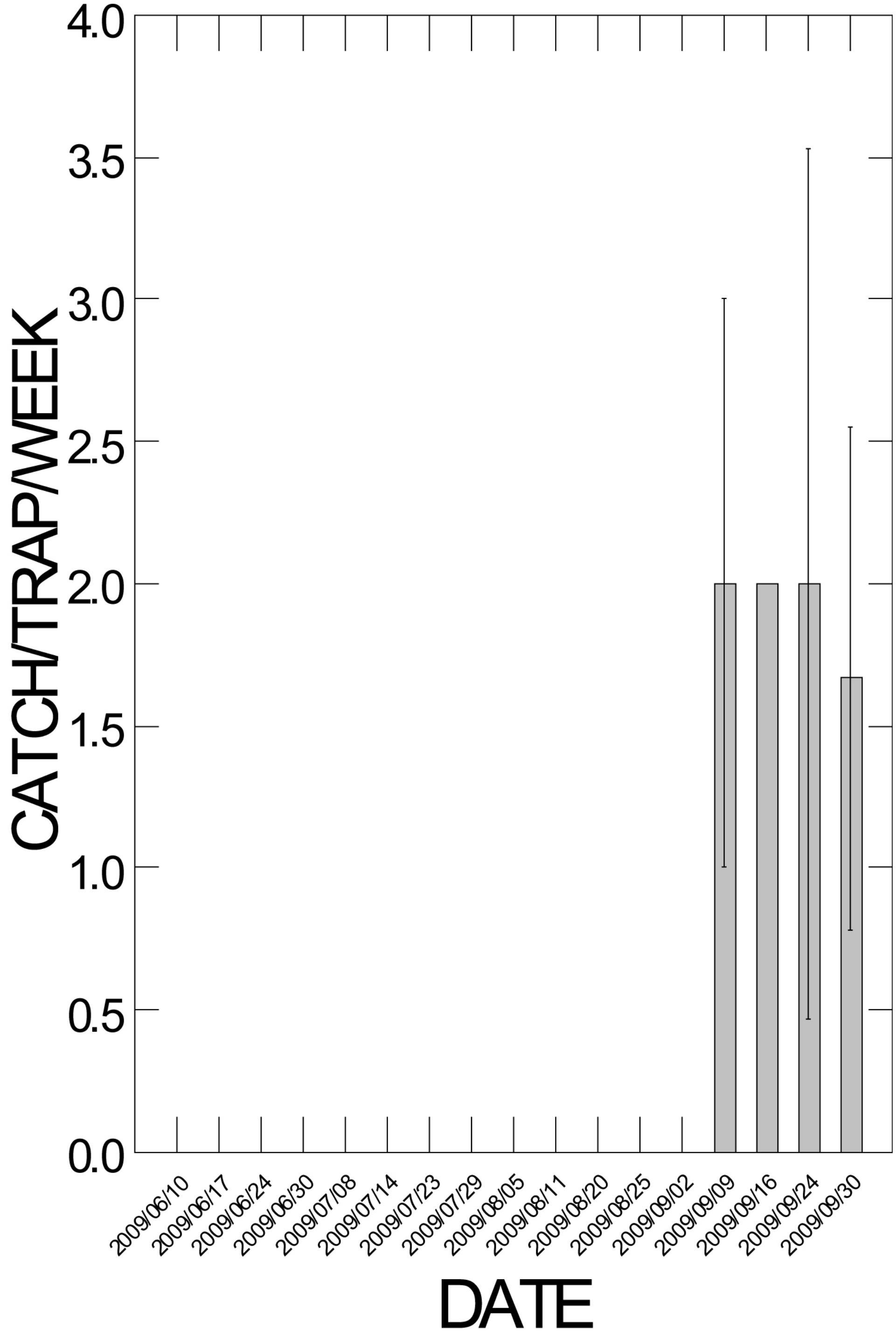


FIG. 13. Catches (mean ± SE) of adult *Scolytus schevyrewi* on baited sticky traps in Otterburne, MB in 2011. Dates are those of trap collection; trapping began on May 4.

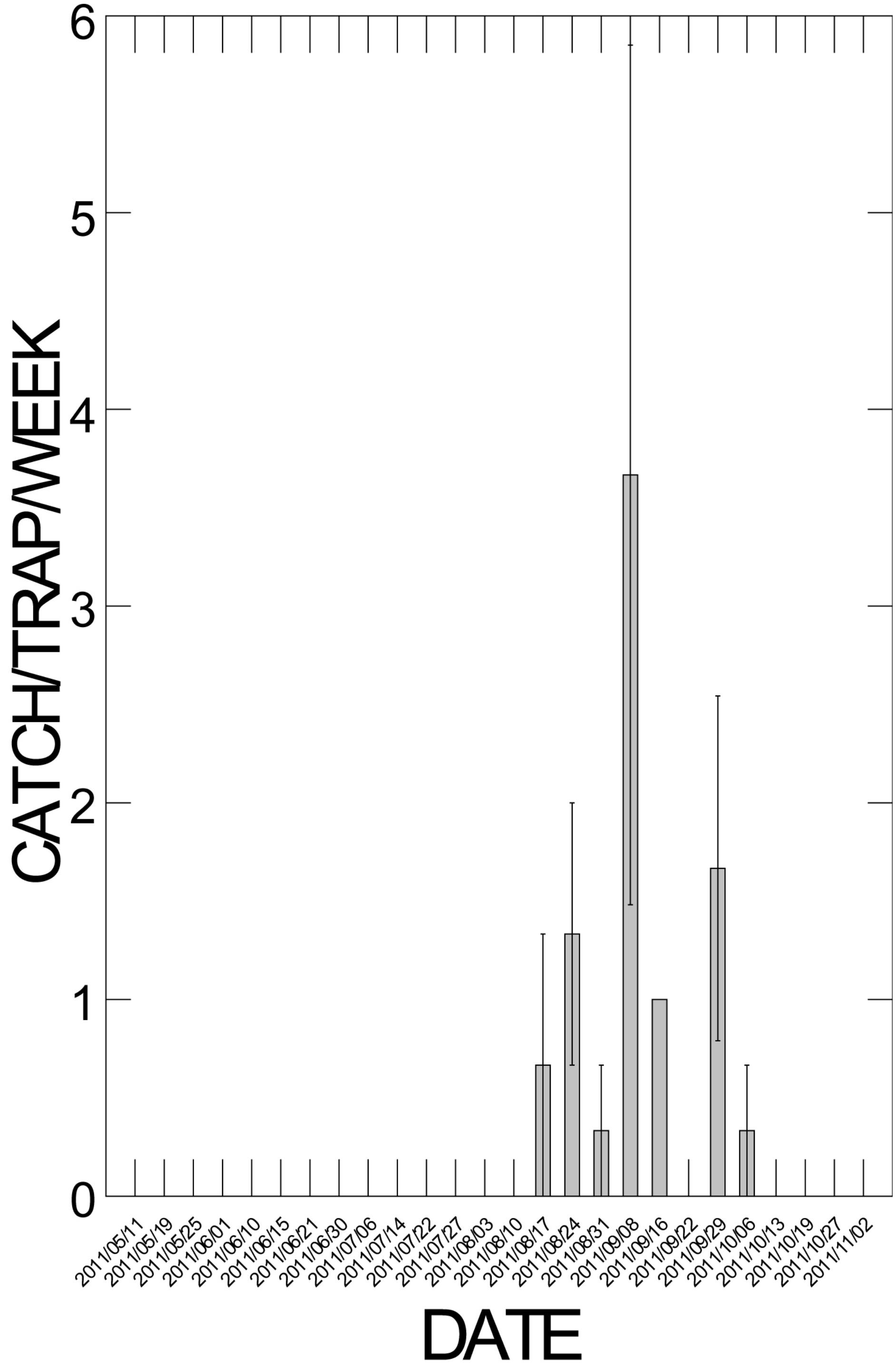


FIG. 14. Catches (mean ± SE) of adult *Scolytus schevyrewi* on baited sticky traps in Carman, MB in 2010. Dates are those of trap collection; trapping began on April 26.

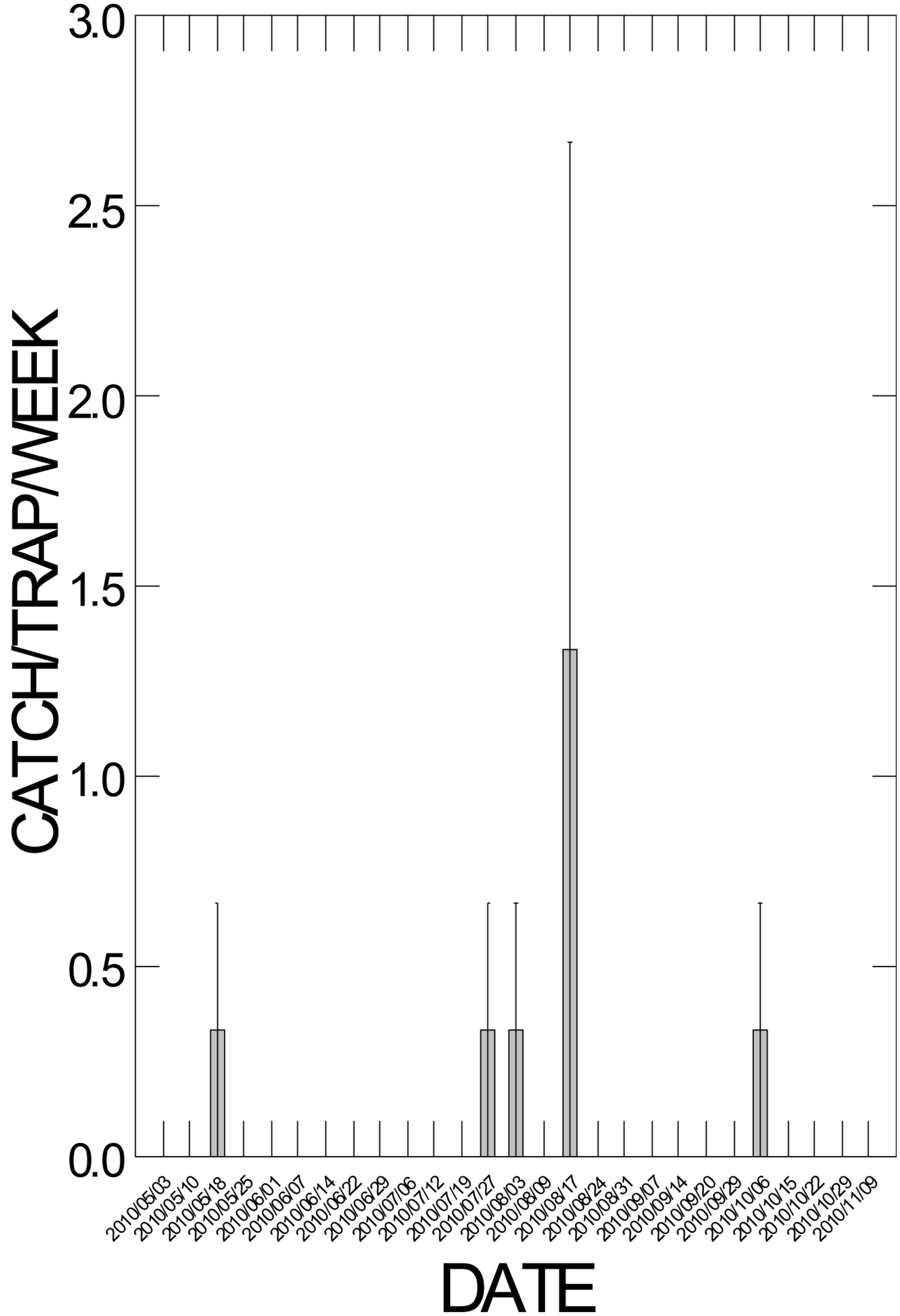


FIG. 15. Catches (mean ± SE) of adult *Scolytus schevyrewi* on baited sticky traps in Carman, MB in 2011. Dates are those of trap collection; trapping began on May 6.

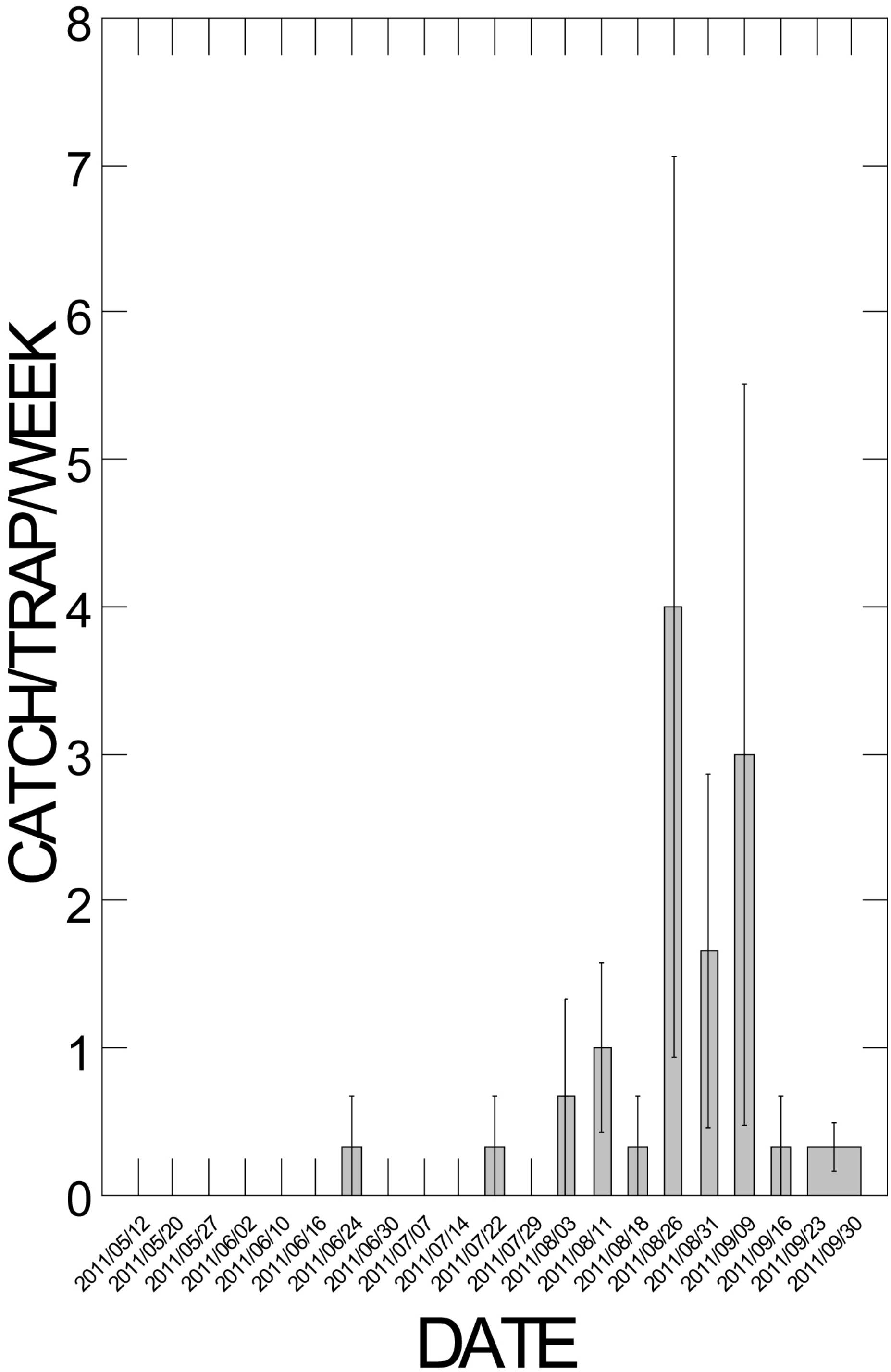


FIG. 16. Number of *Ulmus pumila* trap logs colonized and not colonized by *Scolytus schevyrewi* in relation to the diameter of trap logs. Note: bars are stacked so that total number of logs deployed is indicated by the height of the highest bar for each diameter.

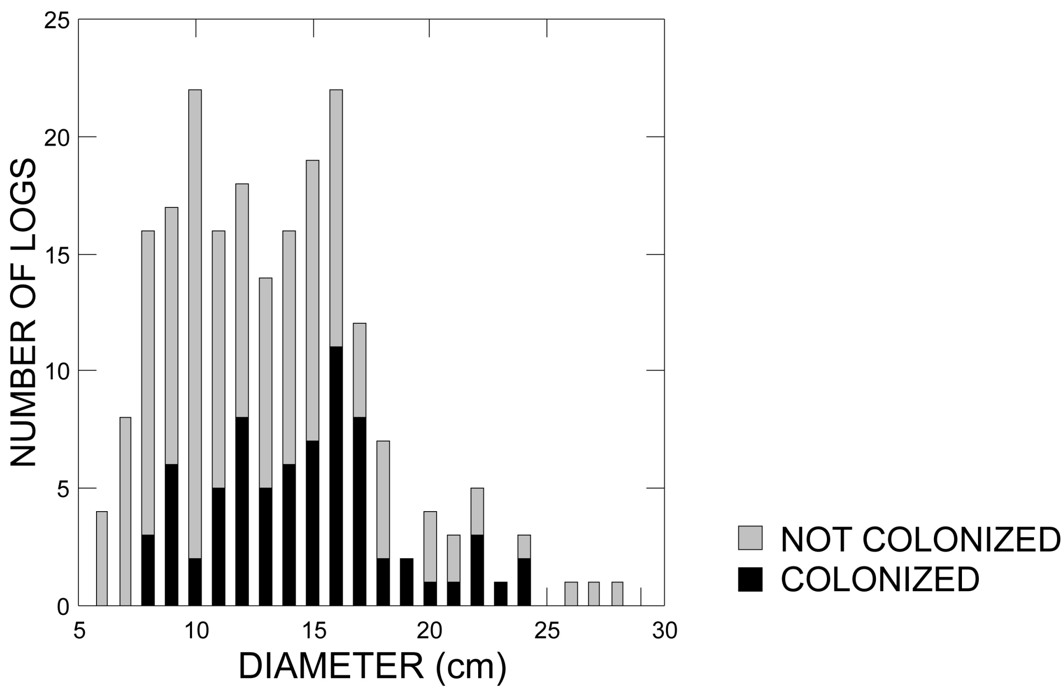


FIG. 17. Means (± SE) of total numbers and mean numbers of different stages of *Scolytus schevyrewi* collected from *Ulmus pumila* trap logs deployed in Carman, MB in relation to the month of removal from the field.

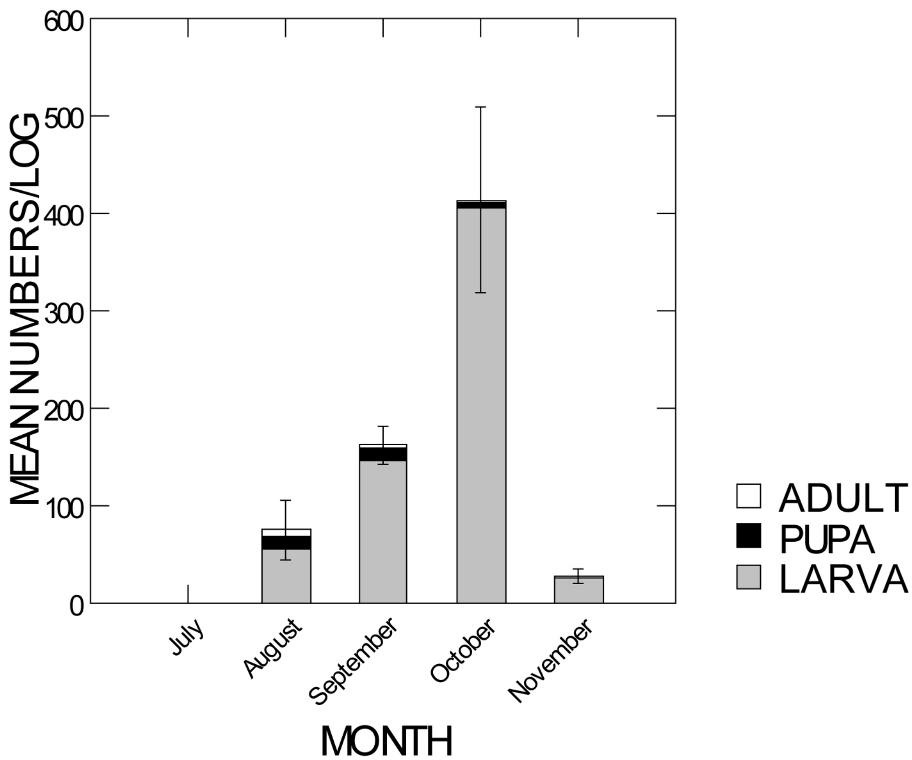


FIG. 18. Means (± SE) of total numbers and mean numbers of different stages of *Scolytus schevyrewi* collected from *Ulmus pumila* trap logs deployed in Swift Current, SK in relation to the month of removal from the field.

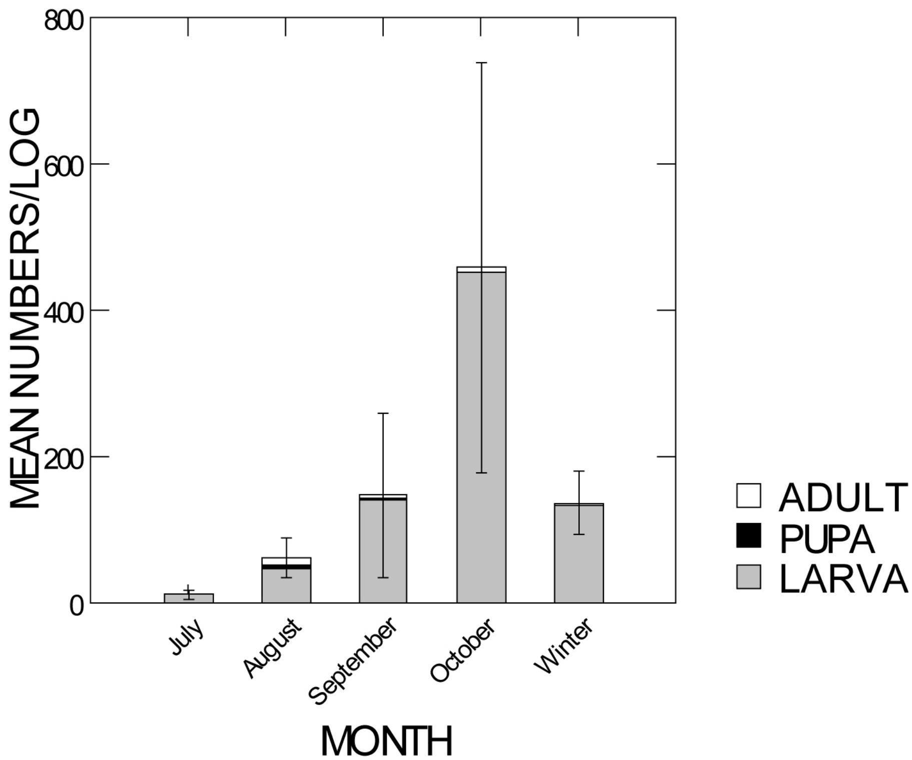


FIG. 19. Numbers of *Scolytus schevyrewi* that emerged from an *Ulmus pumila* log at a constant temperature of 20°C in relation to the number of days from the beginning of the experiment.

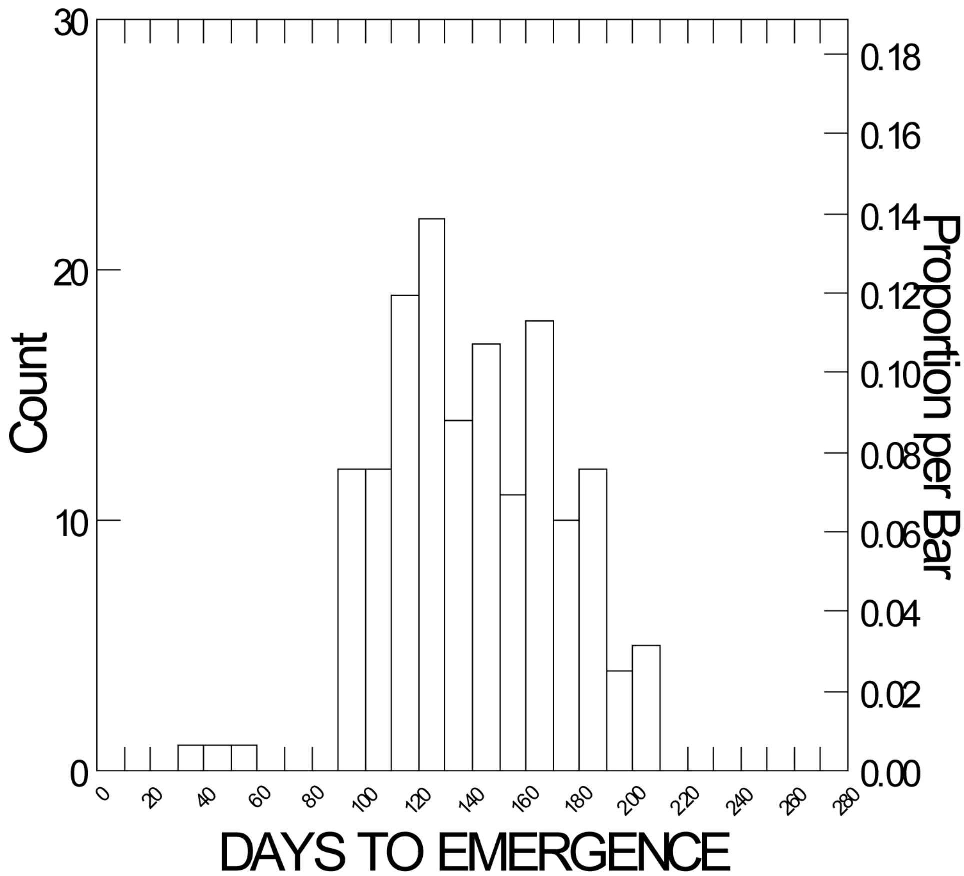


FIG. 20. Numbers of *Scolytus schevyrewi* that emerged from an *Ulmus pumila* log at a constant temperature of 25°C in relation to the number of days from the beginning of the experiment.

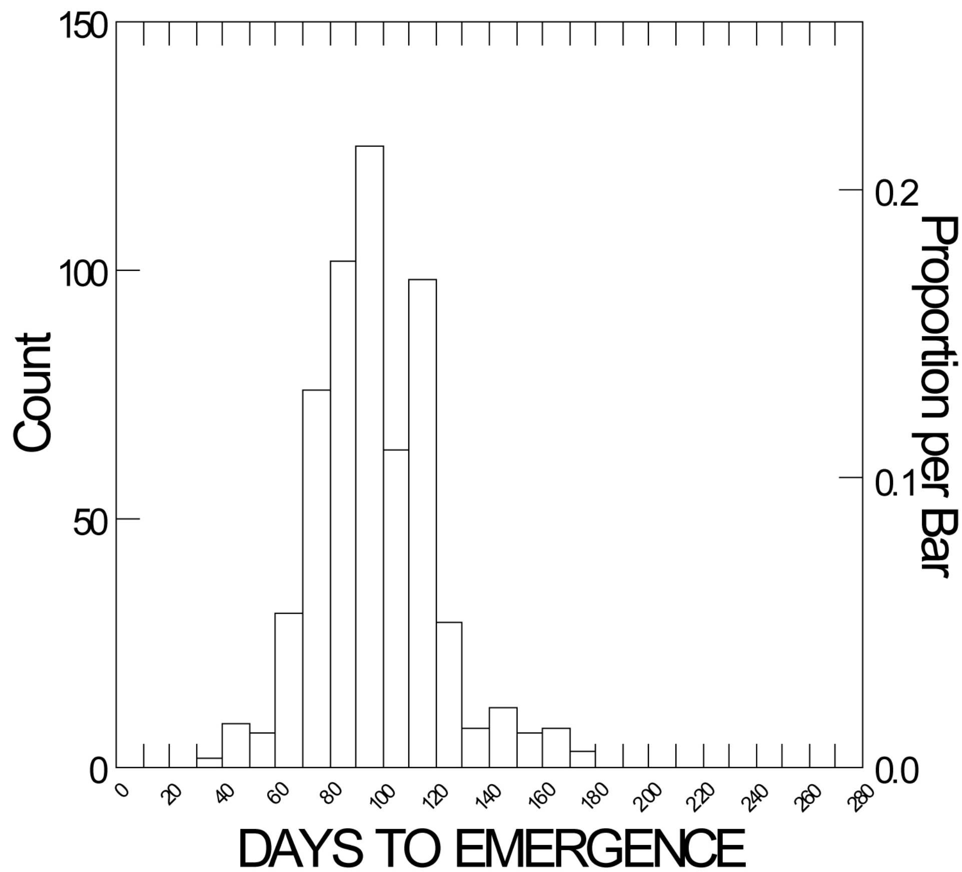
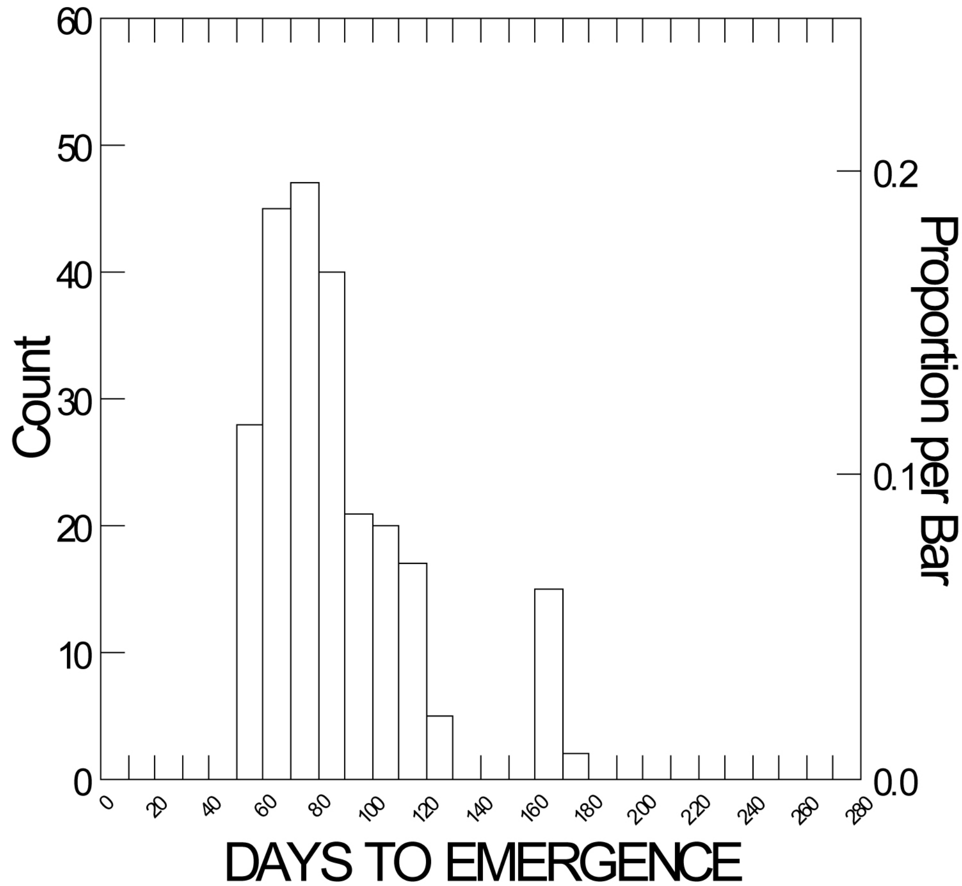


FIG. 21. Numbers of *Scolytus schevyrewi* that emerged from an *Ulmus pumila* log at a constant temperature of 30°C in relation to the number of days from the beginning of the experiment.



DISCUSSION

Experimental methods

The choice of sticky traps for this project seemed logical as this type of trap is used in Dutch elm disease management programs in the Prairies (R. McIntosh, personal communication). Juillet (1963) found that this type of trap catches the most Coleoptera and Hosking (1979) found that, at least for *Dentrotrupes vestibus* Broun, it caught the most scolytines. The numbers of the other two Scolytinae species caught during this trap comparison were very low: eight *Pachycotes peregrinus* (Chapuis), none of which were caught on sticky traps, and a single *Xyleborus saxeseni* (Ratzeburg) caught on a sticky trap (Hosking 1979). Although an appropriate type of trap for my research project on *S. schevyrewi,* it is important to realize that sticky traps only give estimates of numbers of the insect studied (Johnson 1950). Environmental factors probably have an impact on the numbers of *S. schevyrewi* caught; however, it is likely that the temperature threshold for flight is higher than the temperature at which the adhesive material on the sticky traps used in my studies becomes non-sticky (Rudinsky and Vité 1956; Beckwith 1972; E. Kovacs and J. Skendzel, personal communication). Below their respective flight temperature thresholds, insect species cannot fly (Haufe 1966; Johnson 1969). The temperature threshold is unknown for *S. schevyrewi,* but it is probable that the temperature was too cold for *S. schevyrewi* adults to fly at the beginning and end of the sticky trapping period.

Sticky traps were not stapled to utility poles with street lights to avoid having the traps filled by insects attracted to the light source. This, along with the selection of utility poles without transformers, contributed to the uniformity of the baited sticky trap study. For the unbaited sticky trap study, uniformity was achieved in riparian forests by having the traps face the river. Although both Contech's and Great Lakes IPM's sticky traps were used, the latter were only used during unanticipated shortages of the first. There was no intention to compare both traps' efficacy and so experiments were not designed to do so. Great Lakes IPM traps were used in Manitoba communities only and not necessarily in all communities at the same time or over the same period over the years. Consequently, no formal comparison of performance of the trap types can be made and it is necessary to assume that the performance of the trap types does not differ.

The bait used in this project consisted of a tree volatile mimic and a pheromone mimic. The components of the volatile mimic were hexanal, hexanol and sesquiterpenes and the components of the pheromone mix were 4-methyl-3-heptan-1-ol, α-multistriatin, γ-multistriatin and α-cubebene. These pheromone components are similar to the constituent compounds in Multilure, one of four baits tested by Negrón *et al.* (2005) who reported that Multilure was the most effective bait for catching *S schevyrewi.*

Scolytus schevyrewi adults collected on sticky traps, both baited and unbaited, were plated to check for *O. novo-ulmi* growth. Three adult *S. schevyrewi* of seven caught near La Salle in 2008 by Oghiakhe and Holliday (2009) were plated on a malt extract agar, agar and yeast medium and of these, one carried *O. novo-ulmi* spores. None of the 283 *S. schevyrewi* adults plated on this medium in my research project yielded any *O. novo-ulmi* growth. Since no growth was obtained from the 192 *H. rufipes* adults plated either, it was thought that the medium should be changed. One dozen *H. rufipes* adults each were plated on two new media: malt extract, agar and yeast; and the medium used by the Saskatchewan Ministry of Environment (Rory McIntosh, personal communication): potato dextrose, agar and yeast. These proved unsuccessful as well. Growth of fungi and bacteria other than *O. novo-ulmi* was obtained in most plates and it is possible that these pathogens established more rapidly than *O. novo-ulmi* in the media used. Beetles collected on sticky traps left outside for one or two weeks, depending on the part of the project, might not be the best for plating. Hausner *et al.* (2005) used scolytines collected from Lindgren funnel traps and obtained the desired fungal growth. In my study, Lindgren funnel traps, baited with the same bait used for the sticky trap operations, were deployed in sites near the sites where trap logs were deployed. Trap logs having been colonized, *S. schevyrewi* adults were present on these sites; however, none were caught by the Lindgren funnel traps whether or not Ortho Home Defense Max (The Scotts Company LLC, Marysville, Ohio) Vapona® strips (Model 24007, 2011) were used in the collecting cups. Humble *et al.* (2010) were successful in collecting *S. schevyrewi* with Lindgren funnel traps, but they used propylene glycol in the collecting cups that would instantly kill and preserve the beetles. Their method would have been counterproductive for plating.

Trap logs from all tree and shrub species used for the project had a diameter ≥ 5 cm, which is greater than the diameter of the smallest branches in which Yang *et al.* (1988) observed *S. schevyrewi* larvae. Trap logs can be regarded as equivalent to stressed trees. It is possible that batches of logs brought back to the laboratory in July and August were still too wet to be suitable for colonization by *S. schevyrewi.* However for August, this seems unlikely as the percentage of beetles emerging was above 95%. In July 2011 in Carman, only 37% beetles successfully completed their development and emerged from a *U. pumila* trap log collected, but emergence in Swift Current in July 2010 was more than 97%.

Slabs of *U. americana* and *U. pumila* bark were removed from logs kept at 4°C and were used in bark presses (Wermelinger and Seifert 1998) to learn about the development time for each *S. schevyrewi* stage at different temperature regimes and also to learn about the interaction between the beetle and *H. rufipes.* This method was used successfully by Oghiakhe (personal communication) to learn about the development time of *H. rufipes* stages. Although *H. rufipes* did develop successfully in bark presses constructed during my project, no *S. schevyrewi* females laid eggs in the *U. pumila* or *U. americana* bark presses. As a result, it was impossible to use this method to learn about the development time for each stage of the beetle or to learn about interactions with *H. rufipes.* Instead, the bagged log technique was used to study development time.

Larval head capsule width measurements also failed to produce information regarding the development of *S. schevyrewi.* Wang (1992) states that there are five larval instars. Fan *et al.* (2011b) reach the same conclusion using larval head width, body length and body weight. However, their results do not conform to Dyar's rule (Dyar 1890) as the ratios of head width measurements between successive larval instars are not constant. Dyar (1890) had selected the head for his measurements as this body part does not change in size during the instar, but Lekander (1968) suggested that this method does not work with *Scolytus* species.

***Scolytus schevyrewi* distribution**

The highest *S. schevyrewi* catches were in Saskatchewan for all three years of the project (Table 3). In this province, Maple Creek was the community where the annual mean catches were the highest (Table 4). Within Manitoba and Saskatchewan, the southwestern part of the latter province is driest (NRC 2009). The 2009 and 2011 trapping periods were drier than the 2010 trapping period (Fig. 5) and the latter was also the coldest of the three in most communities (Table 5). The numbers of *S. schevyrewi* caught in 2010 were the lowest (Tables 3–4). Of the Chinese regions where studies on *S. schevyrewi* were conducted, Xinjiang is the one from which the highest egg production was recorded (Wang 1992). Of these parts of the country, Xinjiang is also the driest region; however, it is only slightly warmer than Ningxia and about the same as Shaanxi on an annual average (China Culture 2003; Travel China Guide 2012). The number of eggs laid by *S. schevyrewi* females counted by Yang *et al.* (1988) in Shaanxi is below the average number of eggs counted by Wang (1992). In Ningxia, the number of larval galleries stemming from a maternal gallery counted by Fan *et al.* (2011b) is similar to the number of eggs counted by Li *et al.* (1987), also in Xinjiang.

Although more favourable environmental conditions for beetles might explain the geographic and annual variation in numbers of *S. schevyrewi* caught in my study, the dispersal patterns and population growth might also play a part in these differences. In the United States, the first record of *S. schevyrewi* was in Colorado and the beetle was observed in western states before it was first caught in eastern states (Negrón *et al.* 2005).

In Canada, *S. schevyrewi* was observed for the first time in 2006 in Medicine Hat, Alberta (Langor *et al.* 2009; Rory McIntosh, personal communication). In 2011, 600 *S. schevyrewi* adults were collected on baited sticky traps deployed in this community (Feddes-Calpas 2012). Of the communities selected for my project, Maple Creek is the closest to Medicine Hat, followed by Swift Current. In 2011, the numbers of *S. schevyrewi* adults caught were highest in Maple Creek, then in Swift Current while the lowest numbers were caught in Weyburn and Manitoba communities (Table 3). This geographic pattern may change as the invasive phase of *S. schevyrewi* progresses and may be different once the invasive phase is over.

***Scolytus schevyrewi* life cycle**

The earliest *S. schevyrewi* adult caught on sticky traps from any community in any year was on a trap collected on May 18 in Carman in 2010 (Fig. 14). According to Wang (1992), overwintering larvae start pupating when temperatures reach 15°C and, at 18°C, Wang and Chen (2000) found that it takes about 22–34 days for the pupae to become adults. At an unspecified temperature, it takes an extra 2–5 days before these adults emerge (Wang 1992). Based on these numbers, the first adults emerging from overwintering sites could be flying after 24–39 days from the day when temperatures would have reached 15°C. That temperature was first reached on March 29 in Carman in 2010 (Environment Canada 2012) which was 50 days before the first capture. Considering that environmental conditions are so variable in nature and that the maximum daily temperature may fall below 15°C after it has reached it the first time, the first catch in May seems reasonable. This temperature was reached earlier in other communities in 2010 and 2009; however, it is likely that traps were set up early enough as no *S. schevyrewi* were caught on the first week of the trapping period in all communities for all years.

It seems that the seasonal pattern described by Fan *et al.* (2011b) could be the closest to the one observed in Manitoba and Saskatchewan as the climate in the two provinces is similar to the one in Ningxia. In both cases, the first adults emerge in late May and early June and they are present until early October (Fan *et al.* 2011b). In that region of China, the majority of adults emerging from overwintering sites do so in early June (Fan *et al.* 2011b). This emergence might explain the small peak observed early in the season in some flight period graphs (Fig. 7–11, 14–15). However, the emergence of the adults of the next generation peaks in late July in Ningxia (Fan *et al.* 2011b), which is earlier than the peak observed in most communities and years for my project.

Although two peaks, one small and one large, were observed on a majority of the flight period graphs, there was no clear indication of two distinct generations. In China, *S. schevyrewi* has been reported to have two or three overlapping generations (Wang 1992; Fan *et al.* 2011b). This could be explained by the long lasting emergence of adults of each generation as observed on seasonal pattern tables; while the first adult females are already laying eggs, slow maturing larvae are still pupating (Li *et al.* 1987; Wang and Chen 2000; Fan *et al.* 2011b).

Wang (1992) reports that *S. schevyrewi* completes its development in 30.8 days at 26°C and that a generation lasts 40–45 days under field conditions. At an unspecified temperature, but in sheltered conditions, Negrón *et al.* (2005) report a generation time of 30 days. At 20–30°C, the first 1% *S. schevyrewi* adults to emerge from *U. pumila* logs did so in about 50 days after parent beetles were inserted in plastic bags with the logs. The fact that it would take 95 and 65 days for the first 5% adults to emerge at 20°C and 25°C, respectively, suggests that either females delayed laying eggs for a prolonged period or that adults from the following generation were not detected in daily inspections but dug brood galleries and produced brood. Given the long period during which adults were detected following the initial detections, it does seem likely that some adults that were detected were not the immediate progeny of the beetles that were introduced.

Adults from single generations were observed for approximately two months by Li *et al.* (1987), Wang and Chen (2000) and Fan *et al.* (2011b). Data from my research project show that adults were caught from mid to late June and early July until early October; this suggests that more than one generation was present in most communities surveyed in this research (Figs 6–15). The first adults caught in June and July, or May if the environmental conditions are favourable, must be the ones emerging from overwintering sites. Overwintered beetles developing more slowly and emerging later, combined with the first adults from the first generation to emerge, probably explain the steady population increase observed after the first emergence peak. The late summer peak might be the combination of second generation adults developing in 30 days and adults from the first generation developing slower or from eggs laid later. Based on a 45 day generation time, there is potential for another generation with adult emergence at the beginning of October; emergence holes were observed on dissected October, November and winter logs. These emergence holes were connected to galleries in which live larvae were found, so the emergence holes must have been relatively recent. Also, the highest numbers of larvae, pupae and adults found in dissected logs were collected from October trap logs (Figs. 17–18). In trap logs retrieved in November and winter, these numbers had decreased. Perhaps the reduction in numbers is due to larvae and pupae completing their development and emerging as adults. However, it is unlikely that these late adults would have enough time to lay eggs that would successfully develop and emerge the following spring.

As the larval stage was the most frequently found stage in dissected trap logs from all sites and all years, except July 2010, these data did not provide much information on the number of generations either. That this stage was the most represented is logical as it is the longest stage present under the bark (Wang 1992). Except for a period of time in spring, larvae from different generations are present in hosts the entire year (Li *et al.* 1987; Wang and Chen 2000; Fan *et al.* 2011b).

Scolytus schevyrewi larvae, pupae and adults were collected from the winter *U. pumila* trap logs during dissection, but none of the adults were alive. None of the few adults found in the girdled *U. pumila* from Carman were alive (I. Pines, personal communication) after the tree was cut down in October. This is contrary to the observations made by Yang *et al.* (1988) where adults were seen to overwinter as well as larvae. However, Yang *et al.* (1988) do not provide methods and it is not specified whether these adults were found alive during the winter or if they were found in the spring and assumed to have survived the whole winter at that stage. The proportions of overwintering larvae and pupae found in my project are similar to the ones of 98.2% and 1.8%, respectively, observed by Fan *et al.* (2011b). Whether pupae completed their development in spring is unknown. Survival of overwintering *S. schevyrewi* in Manitoba is significantly lower than the survival of the summer generations, and this is consistent with the small numbers of *S. schevyrewi* adults caught on sticky traps at the beginning of the trapping period. The high survival of the brood of the overwintering generation and first generation is also consistent with the steady increase of adults caught on sticky traps throughout the summer.

Scolytus schevyrewi **hosts**

Yang *et al.* (1988) report that *S. schevyrewi* galleries can be in most parts of the host trees, but that 47.7% galleries were found in the "bottom part" of the tree and none were found in branches of a diameter less than 3 cm. The trap log data do not provide any information about the location of brood galleries within a host; however, no galleries were found in branches smaller than 9.5 cm in the girdled *U. pumila* that was cut down in Carman (I. Pines, personal communication). The median diameter of trap logs colonized by *S. schevyrewi* during my project was 18 cm and the smallest ones were 8 cm in diameter. Lee *et al.* (2011) used logs with diameters ranging from about 10–24 cm and found that although the concentration of beetles was higher in smaller logs, the beetle did not have a significant preference for small, 10.2–14 cm, medium, 15.2–19.1 cm, or large logs, 20.3–24.1 cm. However, logs that are too small or too large seem to be unsuitable for brood galleries.

Two girdled *U. pumila* were removed in Carman in the fall; *S. schevyrewi* had not colonized the one that was still wet, but many galleries were found in the dry one, except for one section of the trunk that was still wet (I. Pines, personal communication). Although these two trees were mature, the observations made are consistent with what Shi and Chen (1990) report from their colonization test on young *U. pumila.* In China, *S. schevyrewi* prefers weak hosts (Shi and Chen 1990; Wang 1992). Negrón *et al.* (2005) report the colonization of a drought-stressed *U. americana* in Fort Collins, Colorado; however, it is unclear whether they use the term colonization as it is used in this thesis or if females *S. schevyrewi* digging galleries, without ovipositing, and adults feeding are considered to be colonizing the host.

Both *U. americana* and the exotic *U. pumila* grow naturally on the Prairies (Hildahl and Wong 1965; Gibbs 1978; Anderson and Holliday 2000). From the list of possible host species in Negrón *et al.* (2005), *Salix* and *Prunus* species also grow naturally on the Prairies (Looman and Best 1979). *Caragana arborescens* and *E. angustifolia* were both introduced and are now naturalized on the Prairies (Looman and Best 1979). *Malus* species are planted as ornamentals (personal observation). Although these species are present, in the United States *S. schevyrewi* has only been observed to colonize *U. americana* and *U. pumila* (Lee *et al.* 2011). From logs deployed in Saskatchewan and Manitoba, only *U. pumila* logs were colonized and *S. schevyrewi* adults were only collected on sticky traps stapled to *U. americana* and *U. pumila,* with a marked preference for girdled *U. pumila.* The other species listed in Negrón *et al.* (2005) were probably accidental attacks as is known to happen with *Scolytus* species (Balachowsky

1949; Michalski 1973; Bright 1976; Allen and Humble 2002; Bright and Skidmore 2002). This is most likely the case for the one *S. schevyrewi* adult collected on an *E. angustifolia.* Only 27% of the trap logs from this species had a diameter smaller than 8 cm, the smallest diameter colonized for *U. pumila,* and so, were *E. angustifolia* a host, trap logs from this species should have been suitable. On the other hand, 90% of the *C. arborescens* trap logs deployed had a diameter under 8 cm and 100% had one ≤ 8 cm. In the Prairies, this species is probably never large enough to be suitable for *S. schevyrewi.*

Implications of *Scolytus schevyrewi* establishment in the Prairies

Weak *U. pumila* was the preferred host in my study. Lee *et al.* (2010) captured a significantly greater number of *S. schevyrewi* on *U. pumila* than on *U. americana* logs. This implies that *S. schevyrewi* is less likely to compete with, and maybe displace, *H. rufipes* as the latter species mostly breeds in *U. americana* (Hildahl and Wong 1965), although it may overwinter in *U. pumila* (Anderson and Holliday 2000). Three entrance holes made by *H. rufipes,* but no brood, were located on a section of the cut down girdled *U. pumila* from Carman; this section also had seven entrance holes from *S. schevyrewi* and both live and dead larvae of this species were found (I. Pines, personal communication). The three holes by *H. rufipes* were located at about 1–2 m from the ground and were probably feeding tunnels. Two of the three entrance holes were occupied by a dead *H. rufipes* adult (I. Pines, personal communication).

The preference of *S. schevyrewi* for weak *U. pumila* also implies that the beetle is less likely to carry spores of *O. novo-ulmi* as *U. pumila* is resistant to the Dutch elm disease

(Heybroek 1981). However, the fact that *U. pumila* does not show symptoms of infection does not mean that it is not infected. If it is found that *U. pumila* in the Prairies are asymptomatic reservoirs of *O. novo-ulmi,* then adults emerging from infected *U. pumila* could be carrying *O. novo-ulmi* spores (Harris 2004). Nevertheless, there is no evidence that *S. schevyrewi* can act as a vector of Dutch elm disease. Koski and Jacobi (2007) found spores on feeding wounds made by *S. schevyrewi,* but the disease was not transmitted. Since then, no information has been published about the potential of *S. schevyrewi* as a vector of *O. novo-ulmi* which leads to the belief that it may fail to cause inoculation through its feeding.

Conclusions

Scolytus schevyrewi is established in the Prairies. In Manitoba and Saskatchewan, the beetle has two generations with the possibility of a third one; however, it is unlikely that the adults of the third generation would lay eggs or, at least, that these eggs would successfully develop. The beetle overwinters as a mature larva and, to a lesser extent, as a pupa. Winter survival is low and the population builds up throughout the summer, reaching a peak in late summer.

The preferred host in the Prairies is weak *U. pumila.* This implies that *S. schevyrewi* might not compete with *H. rufipes* and that it is less likely to be exposed to *O. novo-ulmi* spores; however, *S. schevyrewi* is still able to kill stressed *U. pumila* as a result of its feeding and breeding activities (Wang 1992; Negrón *et al.* 2005). Although *S. schevyrewi* prefers stressed *U. pumila* and there is no evidence of its ability to transmit *O. novo-ulmi* to healthy trees, the removal of weak *U. pumila* as part of provincial Dutch elm disease management program could prove beneficial; to leave such trees standing could result in *S. schevyrewi* outbreaks and the colonization of less suitable hosts such as healthy *U. pumila* and *U. americana* as has been observed for other bark beetle species (Coulson 1979; Berryman *et al.* 1984).

It would be of interest to dissect such *U. pumila* that are removed. Dissection of these trees could provide information on the distribution of colonization of the host by *S. schevyrewi.* Samples of *U. pumila* could also be plated to check whether the species can become infected by *O. novo-ulmi* in the Prairies, but remain asymptomatic or if it does not become infected. In the event that *U. pumila* can be infected by *O. novo-ulmi,* it would be important to resolve the issue of plating *S. schevyrewi* to check for *O. novo-ulmi.* Adult *S. schevyrewi* collected from trap logs could be plated instead of adults caught on baited sticky traps.

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APPENDICES

APPENDIX 1. Total catches per trap of adult *Hylurgopinus rufipes* (NEBB) and *Hylesinus aculeatus* (EABB) caught on baited sticky traps in 2009, 2010, and 2011 and species of host trees within 50 m of these traps.

PROVINCE	COMMUNITY	TRAP	HOST TREES WITHIN[a]			NEBB COLLECTED				EABB COLLECTED			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL	2009	2010	2011	TOTAL
MANITOBA	CARMAN	1	none	none	*Ulmus pumila*	N/A	75	6	81	N/A	21	44	65
		2	*Malus* sp.	none	none	N/A	96	71	167	N/A	15	71	86
		3	none	*Ulmus americana*	none	N/A	3	34	37	N/A	0	75	75
		TOTAL				N/A	174	111	285	N/A	36	190	226
	LA SALLE	1	none	none	none	1	0	N/A	1	1	6	N/A	7
		2	none	none	none	1	0	N/A	1	5	3	N/A	8
		3	none	none	none	1	1	N/A	2	5	3	N/A	8
		TOTAL				3	1	N/A	4	11	12	N/A	23
	OTTERBURNE	1	none	none	none	215	197	7	419	80	77	47	204
		2	none	none	none	89	90	14	193	29	35	71	135
		3	none	none	none	66	61	6	133	34	51	24	109
		TOTAL				370	348	27	745	143	163	142	448
	SAINT-ADOLPHE	1	none	none	none	3	4	2	9	7	0	9	16
		2	none	none	none	6	3	0	9	14	0	7	21
		3	none	none	none	5	4	6	15	15	0	16	31
		TOTAL				14	11	8	33	36	0	32	68
	TOTAL					387	534	146	1067	190	211	364	765
SASKATCHEWAN	ASSINIBOIA	1	none	none	none	0	N/A	N/A	0	10	N/A	N/A	10
		2[b]	none	none	none	0	N/A	N/A	0	7	N/A	N/A	7
		3[b]	none	none	none	0	N/A	N/A	0	0	N/A	N/A	0
		4	*Salix* sp., *U. pumila*	none	none	1	N/A	N/A	1	0	N/A	N/A	0
		5[b]	none	none	none	0	N/A	N/A	0	0	N/A	N/A	0
		6	none	none	none	0	N/A	N/A	0	0	N/A	N/A	0
		TOTAL				1	N/A	N/A	1	17	N/A	N/A	17

APPENDIX 1 continued.

PROVINCE	COMMUNITY	TRAP	HOST TREES WITHIN[a]			NEBB COLLECTED				EABB COLLECTED			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL	2009	2010	2011	TOTAL
SASKATCHEWAN	ESTEVAN	1[c]	?	?	?	3	N/A	N/A	3	13	N/A	N/A	13
		2[c]	?	?	?	1	N/A	N/A	1	23	N/A	N/A	23
		3[c]	?	?	?	4	N/A	N/A	4	7	N/A	N/A	7
		4[d]	none	none	none	0	N/A	N/A	0	0	N/A	N/A	0
		5	*U. americana*	none	none	0	N/A	N/A	0	0	N/A	N/A	0
		6	none	none	none	0	N/A	N/A	0	0	N/A	N/A	0
		TOTAL				8	N/A	N/A	8	43	N/A	N/A	43
	MAPLE CREEK	1	*U. americana*	*U. americana*	*U. americana*	0	0	0	0	0	3	9	12
		2	none	*U. americana*	*U. americana*	0	0	0	0	1	1	8	10
		3	none	none	none	0	0	0	0	1	2	5	8
		TOTAL				0	0	0	0	2	6	22	30
	SWIFT CURRENT	1	none	*U. pumila*	*U. pumila*	N/A	0	0	0	N/A	0	6	6
		2	none	none	*U. pumila*	N/A	0	0	0	N/A	3	6	9
		3	none	none	none	N/A	0	0	0	N/A	1	10	11
		TOTAL				N/A	0	0	0	N/A	4	22	26
	WEYBURN	1	none	none	none	N/A	0	1	1	N/A	2	N/A	2
		2	none	none	none	N/A	0	0	0	N/A	2	N/A	2
		3	none	none	none	N/A	1	0	1	N/A	4	N/A	4
		TOTAL				N/A	1	1	2	N/A	8	N/A	8
	TOTAL					9	1	1	11	62	18	44	124
TOTAL						396	535	147	1078	252	229	410	891

[a] As in Negrón *et al.* 2005.

[b] Trap on pole with transformer.

[c] Within first month, traps 1, 2 and 3 changed to new locations (4, 5 and 6, respectively). Hosts not recorded.

[d] Trap on pole with street light.

APPENDIX 2. Weekly catches per trap of adult *Hylurgopinus rufipes* (NEBB) and *Hylesinus aculeatus* (EABB) caught on baited sticky traps in Carman (CA) and Otterburne (OT), MB in 2009, 2010, and 2011.

WEEK OF	NEBB COLLECTED										EABB COLLECTED									
REMOVAL	2009			2010					2011		2009		2010			2011				
	OT1	OT2	OT3	CA1	CA2	OT1	OT2	OT3	CA2	CA3	OT1	OT3	OT1	OT2	OT3	CA1	CA2	CA3	OT1	OT2
05/01	N/A	N/A	N/A	0	0	0	0	0	N/A	N/A	N/A	N/A	6	1	7	N/A	N/A	N/A	N/A	N/A
05/08	N/A	N/A	N/A	0	0	0	0	0	0	0	N/A	N/A	0	0	0	5	15	29	2	3
05/15	N/A	N/A	N/A	N/A	N/A	95	36	30	4	1	N/A	N/A	53	32	39	30	35	28	4	15
05/22	N/A	N/A	N/A	54	70	53	18	15	0	2	N/A	N/A	17	2	4	4	8	2	6	17
05/29	N/A	N/A	N/A	0	0	0	0	0	0	0	N/A	N/A	0	0	0	0	0	0	0	0
06/05	27	13	11	6	13	21	23	10	12	4	25	9	1	0	1	3	12	11	25	19
06/12	113	29	29	9	8	7	3.5	0.5	19	12	45	15	0	0	0	0	0	0	6	9
06/19	70	45	20	N/A	3	7	3.5	0.5	34	15	9	7	0	0	0	0	0	3	2	5
06/26	1	0	1	5	1	2	1	1	0	0	0	0	0	0	0	0	0	0	0	2
07/03	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
07/10	1	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
07/17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07/24	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2	0	0	0	0
07/31	1	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	1	2	0
08/07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08/14	0	0	0	0	0	5	1	1	0	0	0	0	0	0	0	0	0	0	0	0
08/21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08/28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09/04	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	2
09/11	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09/18	0	0	0	0	0	0	0	0	0.5	0	0	1	0	0	0	0	0	0	0	0
09/25	0	0	0	0	0	0	0	0	0.5	0	1	2	0	0	0	0	0	0	0	0
10/02	0	0	0	0	0	2	0	0	N/A	N/A	0	0	0	0	0	N/A	N/A	N/A	0	0
10/09	0	0	0	0	0	0	1	0	N/A	N/A	0	0	0	0	0	N/A	N/A	N/A	0	0
10/16	0	0	0	0	0	0	0	0	N/A	N/A	0	0	0	0	0	N/A	N/A	N/A	0	0
10/23	0	0	0	0	0	0	0	0	N/A	N/A	0	0	0	0	0	N/A	N/A	N/A	0	0
10/30	0	0	0	0	0	0	0	0	N/A	N/A	0	0	0	0	0	N/A	N/A	N/A	0	0
11/06	N/A	N/A	N/A	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

APPENDIX 3. Total catches per trap of adult *Hylurgopinus rufipes* (NEBB) and *Hylesinus aculeatus* (EABB) caught on unbaited sticky traps on *Elaeagnus angustifolia* in 2009, 2010, and 2011 and species of host trees within 50 m of these traps.

PROVINCE	COMMUNITY	TRAP	OTHER HOST TREES WITHIN[a]			NEBB COLLECTED				EABB COLLECTED			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL	2009	2010	2011	TOTAL
SASKATCHEWAN	ESTEVAN	1	*Elaeagnus angustifolia, Ulmus americana*	none	*E. angustifolia, U americana*	0	N/A	N/A	0	1	N/A	N/A	1
		2	*E. angustifolia*	none	*E. angustifolia, U americana*	0	N/A	N/A	0	0	N/A	N/A	0
		3	*E. angustifolia*	none	*E. angustifolia, U americana*	0	N/A	N/A	0	0	N/A	N/A	0
		TOTAL				0	N/A	N/A	0	1	N/A	N/A	1
	SWIFT CURRENT	1	none	*U. americana*	*U. americana*	N/A	0	0	0	N/A	1	7	8
		2	none	none	*Salix alba*	N/A	0	0	0	N/A	0	3	3
		3	none	none	*S. alba*	N/A	0	0	0	N/A	0	0	0
		4	none	none	*S. alba*	N/A	0	0	0	N/A	0	2	2
		5	none	none	*S. alba*	N/A	0	0	0	N/A	0	0	0
		TOTAL				N/A	0	0	0	N/A	1	12	13
	WEYBURN	1	*Caragana arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	N/A	0	0	0	N/A	0	N/A	0
		2	*C. arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	N/A	0	0	0	N/A	0	N/A	0
		3	*C. arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	N/A	0	0	0	N/A	0	N/A	0
		4	*C. arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	N/A	0	0	0	N/A	0	N/A	0
		5	*C. arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	*C. arborescens, E. angustifolia, U. americana*	N/A	0	0	0	N/A	0	N/A	0
		TOTAL				N/A	0	0	0	N/A	0	N/A	0
	TOTAL					0	0	0	0	1	1	12	14

[a] As in Negrón *et al.* 2005.

APPENDIX 4. Total catches per trap of adult *Hylurgopinus rufipes* (NEBB) and *Hylesinus aculeatus* (EABB) caught on unbaited sticky traps on *Salix alba* in 2009, 2010, and 2011 and species of host trees within 50 m of these traps.

PROVINCE	COMMUNITY	TRAP	OTHER HOST TREES WITHIN[a]			NEBB COLLECTED				EABB COLLECTED			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL	2009	2010	2011	TOTAL
MANITOBA	CARMAN	1	*Caragana arborescens, Salix alba*	*C. arborescens, S. alba*	*C. arborescens, S. alba*	N/A	0	0	0	N/A	1	25	26
		2	*C. arborescens, S. alba*	*C. arborescens, S. alba*	*C. arborescens, S. alba*	N/A	0	0	0	N/A	10	77	87
		3	*C. arborescens, S. alba*	*C. arborescens, S. alba*	*C. arborescens, S. alba*	N/A	0	0	0	N/A	32	54	86
		4	*C. arborescens, S. alba*	*C. arborescens, S. alba*	*C. arborescens, S. alba*	N/A	0	0	0	N/A	3	22	25
		5	*C. arborescens, S. alba*	*C. arborescens, S. alba*	*C. arborescens, S. alba*	N/A	0	1	1	N/A	2	7	9
		TOTAL				N/A	0	1	1	N/A	48	185	233
	LA SALLE	1	*S. alba*	*S. alba*	*S. alba*	0	N/A	N/A	0	0	N/A	N/A	0
		2	*S. alba*	*S. alba*	*S. alba*	0	N/A	N/A	0	1	N/A	N/A	1
		3	*S. alba*	*S. alba*	*S. alba*	0	N/A	N/A	0	0	N/A	N/A	0
		4	*S. alba*	*S. alba*	*S. alba*	0	N/A	N/A	0	0	N/A	N/A	0
		5	*S. alba*	*S. alba*	*S. alba*	0	N/A	N/A	0	1	N/A	N/A	1
		TOTAL				0	N/A	N/A	0	2	N/A	N/A	2
	TOTAL					0	0	1	1	2	48	185	235
SASKATCHEWAN	ESTEVAN	1[b]	?	?	?	0	N/A	N/A	0	11	N/A	N/A	11
		2	none	*Ulmus americana*	none	0	N/A	N/A	0	0	N/A	N/A	0
		TOTAL				0	N/A	N/A	0	11	N/A	N/A	11
	TOTAL					0	N/A	N/A	0	11	N/A	N/A	11
TOTAL						0	0	1	1	13	48	185	246

[a] As in Negrón *et al.* 2005.

[b] Within first month, trap 1 changed to new location (2). Hosts not recorded.

APPENDIX 5. Total catches per trap of adult *Hylurgopinus rufipes* (NEBB) and *Hylesinus aculeatus* (EABB) caught on unbaited sticky traps on *Ulmus americana* in 2009, 2010, and 2011 and species of host trees within 50 m of these traps.

PROVINCE	COMMUNITY	TRAP	OTHER HOST TREES WITHIN[a]			NEBB COLLECTED				EABB COLLECTED			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL	2009	2010	2011	TOTAL
MANITOBA	CARMAN	1[b]	*Ulmus americana*	*U. americana*	*U. americana*	N/A	0	4	4	N/A	16	26	42
		2[b]	*U. americana*	*U. americana*	*U. americana*	N/A	38	16	54	N/A	51	13	64
		3[b]	*U. americana*	*U. americana*	*U. americana*	N/A	6	1	7	N/A	2	6	8
		4[b]	*U. americana*	*U. americana*	*U. americana*	N/A	18	0	18	N/A	11	0	11
		5[b]	*U. americana*	*U. americana*	*U. americana*	N/A	12	110	122	N/A	26	34	60
		6[bc]	*U. americana*	*U. americana*	*U. americana*	N/A	19	N/A	19	N/A	53	N/A	53
		7[b]	*U. americana*	*U. americana*	*U. americana*	N/A	90	36	126	N/A	179	39	218
		8[b]	*U. americana*	*U. americana*	*U. americana*	N/A	845	27	872	N/A	47	29	76
		9[b]	*U. americana*	*U. americana*	*U. americana*	N/A	41	8	49	N/A	52	96	148
		10[b]	*U. americana*	*U. americana*	*U. americana*	N/A	70	10	80	N/A	41	75	116
		11[b]	*U. americana*	*U. americana*	*U. americana*	N/A	N/A	24	24	N/A	N/A	37	37
		TOTAL				N/A	1139	236	1375	N/A	478	355	833
	LA SALLE	1[b]	*U. americana*	*U. americana*	*U. americana*	24	N/A	N/A	24	11	N/A	N/A	11
		2[b]	*U. americana*	*U. americana*	*U. americana*	4	N/A	N/A	4	4	N/A	N/A	4
		3[b]	*U. americana*	*U. americana*	*U. americana*	6	N/A	N/A	6	4	N/A	N/A	4
		4[b]	*U. americana*	*U. americana*	*U. americana*	2	N/A	N/A	2	0	N/A	N/A	0
		5[b]	*U. americana*	*U. americana*	*U. americana*	44	N/A	N/A	44	1	N/A	N/A	1
		6[b]	*U. americana*	*U. americana*	*U. americana*	5	N/A	N/A	5	0	N/A	N/A	0
		7[b]	*U. americana*	*U. americana*	*U. americana*	63	N/A	N/A	63	0	N/A	N/A	0
		8[b]	*U. americana*	*U. americana*	*U. americana*	3	N/A	N/A	3	1	N/A	N/A	1
		9[b]	*U. americana*	*U. americana*	*U. americana*	3	N/A	N/A	3	3	N/A	N/A	3
		10[b]	*U. americana*	*U. americana*	*U. americana*	4	N/A	N/A	4	5	N/A	N/A	5
		11[bc]	*U. americana*	*U. americana*	*U. americana*	0	N/A	N/A	0	0	N/A	N/A	0
		12[bc]	*U. americana*	*U. americana*	*U. americana*	0	N/A	N/A	0	0	N/A	N/A	0
		13[bc]	*U. americana*	*U. americana*	*U. americana*	0	N/A	N/A	0	0	N/A	N/A	0
		14[bc]	*U. americana*	*U. americana*	*U. americana*	1	N/A	N/A	1	0	N/A	N/A	0
		TOTAL				159	N/A	N/A	159	29	N/A	N/A	29
	TOTAL					159	1139	236	1534	29	478	355	862

APPENDIX 5 continued.

PROVINCE	COMMUNITY	TRAP	OTHER HOST TREES WITHIN[a]			NEBB COLLECTED				EABB COLLECTED			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL	2009	2010	2011	TOTAL
SASKATCHEWAN	ESTEVAN	1[d]	?	?	?	0	N/A	N/A	0	1	N/A	N/A	1
		2[d]	?	?	?	0	N/A	N/A	0	1	N/A	N/A	1
		3[d]	?	?	?	2	N/A	N/A	2	0	N/A	N/A	0
		4[d]	?	?	?	1	N/A	N/A	1	15	N/A	N/A	15
		5[d]	?	?	?	1	N/A	N/A	1	6	N/A	N/A	6
		6[d]	?	?	?	1	N/A	N/A	1	1	N/A	N/A	1
		7[d]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		8[d]	?	?	?	0	N/A	N/A	0	2	N/A	N/A	2
		9[d]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		10[d]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		11[d]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		12[d]	?	?	?	1	N/A	N/A	1	6	N/A	N/A	6
		13[d]	?	?	?	0	N/A	N/A	0	1	N/A	N/A	1
		14[e]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		15[e]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		16[e]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		17[e]	?	?	?	0	N/A	N/A	0	1	N/A	N/A	1
		18[e]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		19[e]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		20[e]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		21[e]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		22[e]	?	?	?	1	N/A	N/A	1	0	N/A	N/A	0
		23[e]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		24[e]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		25[e]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		26[e]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		27[e]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		28[e]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0

APPENDIX 5 continued.

PROVINCE	COMMUNITY	TRAP	OTHER HOST TREES WITHIN[a]			NEBB COLLECTED				EABB			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL	2009	2010	2011	TOTAL
SASKATCHEWAN	ESTEVAN	29[e]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		30[e]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		31[e]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		TOTAL				7	N/A	N/A	7	34	N/A	N/A	34
	SWIFT CURRENT	1	*U. americana*	*U. americana, Ulmus pumila*	*U. americana*	N/A	0	0	0	N/A	0	2	2
		2	*U. americana*	*U. americana, U. pumila*	*U. americana*	N/A	0	0	0	N/A	2	4	6
		3	*U. americana*	*U. americana, U. pumila*	*U. americana*	N/A	1	0	1	N/A	0	2	2
		4	*U. americana, U. pumila*	*U. americana*	*U. americana*	N/A	0	0	0	N/A	0	0	0
		5	*U. americana*	*U. americana, U. pumila*	*U. americana*	N/A	0	0	0	N/A	0	0	0
		6	*U. americana*	*U. americana, U. pumila*	*U. americana*	N/A	0	0	0	N/A	3	4	7
		7	*U. americana*	*U. americana, U. pumila*	*U. americana*	N/A	0	0	0	N/A	0	0	0
		8	*U. americana*	*U. americana, U. pumila*	*U. americana*	N/A	0	0	0	N/A	2	1	3
		9	*U. americana*	*U. americana*	*U. americana, U. pumila*	N/A	0	0	0	N/A	0	0	0
		10	*U. americana*	*U. americana*	*U. americana, U. pumila*	N/A	0	0	0	N/A	0	0	0
		TOTAL				N/A	1	0	1	N/A	7	13	20
	WEYBURN	1	*Caragana arborescens, U. americana*	*C. arborescens, U. americana*	*C. arborescens, U. americana*	N/A	0	0	0	N/A	1	N/A	1
		2	*C. arborescens, U. americana*	*C. arborescens, U. americana*	*C. arborescens, U. americana*	N/A	0	0	0	N/A	0	N/A	0
		3	*C. arborescens, U. americana*	*C. arborescens, U. americana*	*C. arborescens, U. americana*	N/A	0	0	0	N/A	0	N/A	0
		4	*C. arborescens, U. americana*	*C. arborescens, U. americana*	*C. arborescens, U. americana*	N/A	0	2	2	N/A	1	N/A	1
		5	*C. arborescens, U. americana*	*C. arborescens, U. americana*	*C. arborescens, U. americana*	N/A	0	0	0	N/A	0	N/A	0
		6	*U. americana*	*U. americana*	*C. arborescens, U. americana*	N/A	0	0	0	N/A	15	N/A	15

APPENDIX 5 continued.

PROVINCE	COMMUNITY	TRAP	OTHER HOST TREES WITHIN[a]			NEBB COLLECTED				EABB COLLECTED			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL	2009	2010	2011	TOTAL
SASKATCHEWAN	WEYBURN	7	*U. americana*	*U. americana*	*C. arborescens, U. americana*	N/A	0	0	0	N/A	5	N/A	5
		8	*U. americana*	*U. americana*	*C. arborescens, U. americana*	N/A	0	0	0	N/A	3	N/A	3
		9	*U. americana*	*U. americana*	*C. arborescens, U. americana*	N/A	0	0	0	N/A	5	N/A	5
		10	*U. americana*	*U. americana*	*C. arborescens, U. americana*	N/A	0	0	0	N/A	20	N/A	20
		TOTAL				N/A	0	2	2	N/A	50	N/A	50
	TOTAL					7	1	2	10	34	57	13	104
TOTAL						166	1140	238	1544	63	535	368	966

[a] As in Negrón *et al.* 2005.

[b] In riparian forest.

[c] Infected with Dutch elm disease.

[d] Within first month, traps 1 to 13 changed to new locations. Hosts not recorded.

[e] Hosts not recorded.

APPENDIX 6. Total catches per trap of adult *Hylurgopinus rufipes* (NEBB) and *Hylesinus aculeatus* (EABB) caught on unbaited sticky traps on *Ulmus pumila* in 2009, 2010, and 2011 and species of host trees within 50 m of these traps.

PROVINCE	COMMUNITY	TRAP	OTHER HOST TREES WITHIN[a]			NEBB COLLECTED				EABB COLLECTED			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL	2009	2010	2011	TOTAL
MANITOBA	CARMAN	1	*Ulmus pumila*	*U. pumila*	*U. pumila*	N/A	9	5	14	N/A	3	8	11
		2	*U. pumila*	*U. pumila*	*U. pumila*	N/A	3	0	3	N/A	2	11	13
		3	*U. pumila*	*U. pumila*	*U. pumila*	N/A	1	7	8	N/A	2	8	10
		4	*U. pumila*	*U. pumila*	*U. pumila*	N/A	0	2	2	N/A	3	6	9
		5	*U. pumila*	*U. pumila*	*U. pumila*	N/A	2	0	2	N/A	3	4	7
		TOTAL				N/A	15	14	29	N/A	13	37	50
	LA SALLE	1	*U. pumila*	*U. pumila*	*U. pumila*	5	N/A	N/A	5	1	N/A	N/A	1
		2	*U. pumila*	*U. pumila*	*U. pumila*	7	N/A	N/A	7	2	N/A	N/A	2
		3	*U. pumila*	*U. pumila*	*U. pumila*	1	N/A	N/A	1	1	N/A	N/A	1
		4	*U. pumila*	*U. pumila*	*U. pumila*	1	N/A	N/A	1	1	N/A	N/A	1
		5	*U. pumila*	*U. pumila*	*U. pumila*	3	N/A	N/A	3	2	N/A	N/A	2
		TOTAL				17	N/A	N/A	17	7	N/A	N/A	7
	TOTAL					17	15	14	46	7	13	37	57
SASKATCHEWAN	ESTEVAN	1[b]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		2[b]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		3[b]	?	?	?	6	N/A	N/A	6	1	N/A	N/A	1
		4[b]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		5[b]	?	?	?	2	N/A	N/A	2	1	N/A	N/A	1
		6[c]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		7[c]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		8[c]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		9[c]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		10[c]	?	?	?	1	N/A	N/A	1	0	N/A	N/A	0
		11[c]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		12[c]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		13[c]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		14[c]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		15[c]	?	?	?	0	N/A	N/A	0	0	N/A	N/A	0
		TOTAL				9	N/A	N/A	9	2	N/A	N/A	2

APPENDIX 6 continued.

PROVINCE	COMMUNITY	TRAP	OTHER HOST TREES WITHIN[a]			NEBB COLLECTED				EABB COLLECTED			
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	2009	2010	2011	TOTAL	2009	2010	2011	TOTAL
SASKATCHEWAN	SWIFT CURRENT	1	*U. pumila*	*Ulmus americana, U. pumila*	*U. americana, U. pumila*	N/A	0	0	0	N/A	0	1	1
		2	*U. pumila*	*U. pumila*	*U. americana, U. pumila*	N/A	0	0	0	N/A	0	2	2
		3	*U. pumila*	*U. pumila*	*U. pumila*	N/A	0	0	0	N/A	1	3	4
		4	*U. pumila*	*U. pumila*	*U. pumila*	N/A	0	0	0	N/A	0	0	0
		5	*U. americana*	*U. americana*	*U. americana*	N/A	0	0	0	N/A	1	0	1
		TOTAL				N/A	0	0	0	N/A	2	6	8
	WEYBURN	1	*Malus* sp., *U. pumila*	*U. americana, U. pumila*	*U. americana, U. pumila*	N/A	1	9	10	N/A	0	N/A	0
		2	*Malus* sp., *U. pumila*	*U. americana, U. pumila*	*U. americana, U. pumila*	N/A	0	0	0	N/A	0	N/A	0
		3	*Malus* sp., *U. pumila*	*U. pumila*	*U. americana, U. pumila*	N/A	1	0	1	N/A	0	N/A	0
		4	*Malus* sp., *U. pumila*	*U. pumila*	*U. americana, U. pumila*	N/A	0	1	1	N/A	0	N/A	0
		5	*Malus* sp., *U. pumila*	*U. pumila*	*U. americana, U. pumila*	N/A	1	1	2	N/A	0	N/A	0
		6[d]	*Caragana arborescens, U. pumila*	*C. arborescens, U. pumila*	*C. arborescens, U. pumila*	N/A	N/A	0	0	N/A	N/A	N/A	N/A
		7[d]	*C. arborescens, U. pumila*	*C. arborescens, U. pumila*	*C. arborescens, U. pumila*	N/A	N/A	0	0	N/A	N/A	N/A	N/A
		8[d]	*C. arborescens, U. pumila*	*C. arborescens, U. pumila*	*C. arborescens, U. pumila*	N/A	N/A	0	0	N/A	N/A	N/A	N/A
		9[d]	*C. arborescens, U. pumila*	*C. arborescens, U. pumila*	*C. arborescens, U. pumila*	N/A	N/A	0	0	N/A	N/A	N/A	N/A
		TOTAL				N/A	3	11	14	N/A	0	N/A	0
	TOTAL					9	3	11	23	2	2	6	10
TOTAL						26	18	25	69	9	15	43	67

[a] As in Negrón *et al.* 2005.

[b] Within first month, traps 1 to 5 changed to new locations. Hosts not recorded.

[c] Hosts not recorded.

[d] Girdled, but not paired with healthy *U. pumila.*

APPENDIX 7. Total catches per trap of adult *Hylurgopinus rufipes* (NEBB) and *Hylesinus aculeatus* (EABB) caught on unbaited sticky traps on healthy *Ulmus pumila* paired with girdled *U. pumila* in 2011 and species of host trees within 50 m of these traps.

PROVINCE	COMMUNITY	PAIR[a]	OTHER HOST TREES WITHIN[b]			NEBB COLLECTED		EABB COLLECTED	
			≤ 10 m	> 10 m and ≤ 25 m	> 25 m and ≤ 50 m	HEALTHY	GIRDLED	HEALTHY	GIRDLED
MANITOBA	CARMAN	1	*Ulmus pumila*	*U. pumila*	girdled *U. pumila, U. pumila*	26	17	10	14
		2	*U. pumila*	*U. pumila*	girdled *U. pumila, U. pumila*	6	42	9	36
		3	*Salix alba, U. pumila*	*S. alba, U. pumila*	*S. alba,* girdled *U. pumila, U. pumila*	6	82	5	2
		4	*S. alba, U. pumila*	*S. alba, U. pumila*	*S. alba,* girdled *U. pumila, U. pumila*	4	227	2	1
		5	*S. alba, U. pumila*	*S. alba, U. pumila*	*S. alba,* girdled *U. pumila, U. pumila*	7	1146	3	1
		TOTAL				49	1514	29	54
SASKATCHEWAN	SWIFT CURRENT	1	*Elaeagnus angustifolia, Prunus* sp.	*E. angustifolia, Prunus spp., Ulmus americana, U. pumila*	*E. angustifolia, Prunus spp., U. americana, U. pumila*	0	0	0	2
		2	*U. americana*	*E. angustifolia, Prunus* spp., *U. americana, U. pumila*	*E. angustifolia, Prunus* spp., *S. alba, U. americana, U. pumila*	0	1	1	2
		3	none	*U. americana, U. pumila*	*S. alba, Prunus* spp., *U. americana, U. pumila*	0	0	1	0
		TOTAL				0	1	2	4
TOTAL						49	1515	31	58

[a] Trees from one pair are separated by 20 m.

[b] As in Negrón *et al.* 2005.

APPENDIX 8. Frequency with which dissected trap logs of five tree species were colonized by *Hylurgopinus rufipes*. Data include trap logs that were dissected after having been removed from emergence cylinders. Note: no logs were colonized by *Hylesinus aculeatus*.

TREE SPECIES	YEAR[a]	MANITOBA					SASKATCHEWAN							AVERAGE
		CARMAN		LA SALLE		AVERAGE	ASSINIBOIA		SWIFT CURRENT		WEYBURN		AVERAGE	(%)
		COLONIZED (%)	*n*	COLONIZED (%)	*n*	(%)	COLONIZED (%)	*n*	COLONIZED (%)	*n*	COLONIZED (%)	*n*	(%)	
Caragana arborescens		N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	10	N/A	N/A	0	0
Elaeagnus angustifolia		N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	54	N/A	N/A	0	0
Salix alba		0	119	0	24	0	0	23	N/A	N/A	N/A	N/A	0	0
Ulmus americana	2009	N/A	N/A	79	24	79	0	7	N/A	N/A	N/A	N/A	0	40
	2010	5	44	N/A	N/A	5	N/A	N/A	2	55	N/A	N/A	2	3
	2011	64	22	N/A	N/A	64	N/A	N/A	0	24	N/A	N/A	0	32
	AVERAGE	34		79		49	0		1		N/A		1	25
Ulmus pumila		0	79	0	22	0	0	30	0	75	0	6	0	0

[a] For species of host trees other than *U. americana*, the three years have been pooled.

APPENDIX 9. Total numbers of *Hylurgopinus rufipes* at different stages found in dissected *Ulmus americana* trap logs from La Salle in relation to removal date. Note: no logs were colonized by *Hylesinus aculeatus.*

MONTH	YEAR	GALLERY	STAGE			TOTAL
			LARVA	PUPA	ADULT	
AUGUST	2009	130	2466	0	94	2560
	2009	7	47	0	3	50
	TOTAL		2513	0	97	2610
SEPTEMBER	2009	55	778	60	7	845
	2009	4	103	0	1	104
	2009	60	1547	79	74	1700
	TOTAL		2428	139	82	2649
OCTOBER	2009	21	179	9	33	221
	2009	2	2	0	0	2
	TOTAL		181	9	33	223
WINTER	2009	137	1377	6	221	1604
	2009	1	10	1	0	11
	2009	66	472	12	107	591
	2009	95	1087	8	113	1208
	2009	258	980	10	329	1319
	2009	97	196	3	74	273
	TOTAL		4122	40	844	5006

APPENDIX 10. Total numbers of *Hylurgopinus rufipes* at different stages found in dissected *Ulmus americana* trap logs from Carman in relation to removal date and percentage of adult beetles marked with fluorescent powder. Note: no logs were colonized by *Hylesinus aculeatus.*

MONTH	YEAR	GALLERY	STAGE			TOTAL	FLUORESCENT POWDER	
			LARVA	PUPA	ADULT		ON LOG	ON ADULT
JULY	2011	5	7	0	0	7	YES	N/A
	2011	1	0	0	0	0	YES	N/A
	TOTAL		7	0	0	7		
AUGUST	2011	5	130	22	7	159	YES	1[a]
	TOTAL		130	22	7	159		
SEPTEMBER	2011	4	17	2	4	23	YES	1
	TOTAL		17	2	4	23		
OCTOBER	2011	21	7	3	10	20	YES	3
	2011	1	1	0	0	1	YES	N/A
	2011	3	4	0	0	4	YES	N/A
	TOTAL		12	3	10	25		
NOVEMBER	2010	1	2	13	22	37	NO	N/A
	TOTAL		2	13	22	37		

[a] Only five of the seven adults could be checked for fluorescent powder.

APPENDIX 11. Numbers of adult *Hylurgopinus rufipes* that emerged from *Ulmus americana* trap logs in emergence cylinders and numbers of the same species at different stages found in these trap logs after dissection. Note: no logs were colonized by *Hylesinus aculeatus*.

SUMMER				WINTER			
YEAR	EMERGED	DEAD	SURVIVAL (%)	INTERVAL	EMERGED	DEAD	SURVIVAL (%)
2009	N/A	N/A	N/A				
				2009–2010	456	1481	23.5
2010	N/A	N/A	N/A				
				2010–2011	2	1	66.7
2011	804	4	99.5				
TOTAL	804	4	99.5		458	1482	23.6