The Banded Elm Bark Beetle: A New Threat to Elms in North America

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Abstract: An exotic bark beetle from Asia, the banded elm bark beetle, *Scolytus schevyrewi*, has been discovered in 21 states of the United States. Although its point of entry is not known, a survey of museum specimens suggests that it has been in the US for at least 10 years. It is most abundant in western states, attacks primarily American and Siberian elms, and carries spores of the fungal pathogen for Dutch elm disease. In Colorado, *S. schevyrewi* appears to compete successfully with the more familiar smaller European elm bark beetle, *Scolytus multistriatus*. The host range, chemical ecology, and impact of *S. schevyrewi* are under investigation. The insect will likely have a significant deleterious effect on elms in the urban and peri-urban landscapes of North America.

On 1 and 28 April 2003, an exotic elm bark beetle, *Scolytus schevyrewi* Semenov (Coleoptera: Scolytidae) (Fig. 1), was detected among insects caught in Lindgren funnel traps (Lindgren 1983) in Aurora, CO, and Ogden, UT. The specimens in Colorado were collected in traps baited with a general attractant for woodborers (α-pinene and ethanol), whereas the specimens in Utah were collected in traps baited with ethanol or with the 3-component aggregation pheromone of the Eurasian spruce engraver, *Ips typographus* (L.) (Coleoptera: Scolytidae). These traps were deployed as part of the joint USDA Forest Service and USDA APHIS-PPQ Rapid Detection and Response Pilot Project for exotic bark beetles (USDA Forest Service 2001). Initial identification was made by S. L. Wood, Brigham Young University, Provo, UT. Detection sites were near facilities that recycle solid-wood packing material. Given that this material has been a high-profile source of many other invasive bark beetles and woodborers (USDA 2000, Haack 2001), the collections at these localities immediately raised suspicion that the beetles emerged from wood products at these facilities.

On 21 May 2003, *S. schevyrewi* was also found in Lakewood, Colorado, infesting branches of

Fig. 1. Adult male banded elm bark beetle, *Scolytus schevyrewi* Semenov (photo by José Negrón).

Fig. 2. States where *Scolytus schevyrewi* has been collected and positively identified as of April 2005. Information is based on the National Agricultural Pest Information System web site (http://ceris.purdue.edu/napis/pests/barkb/imap/schevy.html), except for records from Missouri, New Jersey, and Oklahoma, which are based on personal correspondence with Dennis Haugen, USDA Forest Service, Forest Health Protection, St. Paul, MN (Missouri record), personal correspondence with E. R. Hoebeke, Cornell University (New Jersey record), and a specimen collected at a private residence (Oklahoma record, see text). Examination of determined and undetermined Scolytidae in the following museum collections has not revealed any additional distributional information: California Academy of Sciences, California Department of Food and Agriculture, Milwaukee Public Museum, South Dakota State University, University of California, Berkeley, University of California, Davis, University of Minnesota, University of Wisconsin, and University of Wyoming.

Siberian elm, *Ulmus pumila* L., which broke and fell after a late snowstorm. It is not known whether these branches were infested before breakage. On 27 June 2003, beetles were collected in Fort Collins, CO, on recently cut logs of American elm, *Ulmus americana* L. Similar collections were made on 18 August 2003 in Reno, NV, from cut branches and sections of stems of *U. americana* and *U. pumila*. By December 2004, additional funnel trap surveys and evaluation of previously collected specimens had placed the insect in 18 additional states (Fig. 2). At the time of this publication, it had not been reported from Canada (D. E. Bright, retired, Agriculture and Agri-Food Canada, and L. M. Humble, Natural Resources Canada, Canadian Forestry Service, Pacific Forestry Centre, personal communications) or Mexico (J. E. Macías Sámano, El Colegio de la Frontera Sur, Chiapas, personal communication).

Scolytus schevyrewi is native to China (Shi and Chen 1990, Wang 1992, Liu and Haack 2003) and Central Asia (Sokanovskii 1960), where it colonizes elms and is reported from other hardwoods. The point of introduction into the United States is unknown, but the current distribution suggests an introduction in western North America. The case of *S. schevyrewi* in North America underscores the difficulties of predicting and planning for management responses to exotic insects. Of 6,825 USDA APHIS interception records of bark beetles (Scolytidae) between 1985 and 2000, only 102 were from the genus *Scolytus*, and none were identified to species as *S. schevyrewi* (Haack 2001). Thus, the species was essentially unknown to North American entomologists when the beetle first surfaced in April 2003.

In Fort Collins, *S. schevyrewi* co-colonizes American and Siberian elms along with the more familiar smaller European elm bark beetle, *Scolytus multistriatus* (Marsham), which is also an exotic species. The past century of research on *S. multistriatus* in North America provides an important reservoir of knowledge that can be applied to predict and understand the biology and potential impact of *S. schevyrewi*. In the 1970s, the association of *S. multistriatus* populations with Dutch elm disease (DED) caused by the fungal pathogen *Ophiostoma novo-ulmi* Brasier was studied in Fort Collins (Cuthbert and Peacock 1979), where large populations of *S. schevyrewi* are now present.

Scolytus schevyrewi and *S. multistriatus* can be

Fig. 3. Elytra from a series of adult *Scolytus schevyrewi* from Fort Collins, CO. The banding pattern varies from nearly absent to covering about half of the elytron, depending on the individual (photos by James LaBonte).

distinguished by a dark transverse band across the elytra of *S. schevyrewi* (Figs. 1 and 3), the more posterior placement of the single ventral spine on the second abdominal sternite of *S. schevyrewi*, and by the presence of posteriolateral teeth on abdominal sternites 2, 3, and 4 on *S. multistriatus*, among other characters (LaBonte et al. 2003). The generally diagnostic banding pattern on *S. schevyrewi*, which is the source of its common name, is quite variable, leading to the consideration of the genetic basis of this morphological trait. *Scolytus multistriatus* is 2–3 mm long, slightly smaller than *S. schevyrewi* (3–4 mm long), yet large specimens of *S. multistriatus* can overlap in length with small specimens of *S. schevyrewi*.

Distribution

In Asia, *S. schevyrewi* occurs in the northern Chinese provinces of Beijing, Hebei, Heilongjiang, Henan, Ningxia, Shaanxi, and Xinjiang, as well as in Korea, Mongolia, Russia, Kazakhstan, Uzbekistan, Kyrgyzstan, Turkmenistan, and Tajikistan (Michalski 1973; Krivolutskaya 1983; Wang 1992; Wood and Bright 1992; Bright and Skidmore 1997, 2002; Liu and Haack 2003) (Fig. 4). In the United States, the nearly simultaneous discovery of *S. schevyrewi* in many states indicates that the insect is not a recent introduction, but has been present for several years. Indeed, a survey of museum collections has revealed that *S. schevyrewi* was collected in 1994 (CO: Denver Co., Denver, *ex*. American elm, August 1994, D. Leatherman, collector; specimen in the C. P. Gillette Museum of Arthropod Diversity at Colorado State University). In 1998 (NM: Curry Co., Clovis, trunk of dead elm, 3 October 1998, C. Sutherland, collector and personal communication) the beetle was collected from dying elms at Hillcrest Park and the City of Clovis Municipal Golf Course (specimens in the New Mexico State University Arthropod Collection). The beetle also was collected in 2000 inside a residence in Clinton, Custer County, OK. Finally, as part of a statewide survey for exotic woodboring insects, specimens of *S. schevyrewi* were collected in 2002 from southern California (Los Angeles Co., City of Industry, 1 July 2002, T. Galindo, collector; R. L. Penrose, California Department of Food and Agriculture, personal communication) from funnel traps baited with ethanol and α-pinene. Detailed United States collection records by county are presented in LaBonte (unpublished).

Fig. 4. Approximate distribution of *Scolytus schevyrewi* in Asia (Map of Asia from Planiglobe. kk+w - digitale kartography GmbH, Kiel, Germany; http://www.planiglobe.com).

Hosts

In its native range, *S. schevyrewi* has been reported from host trees in five families, but the primary hosts are various species of elm (Table 1). Of these Asian elm hosts, Siberian elm has been widely planted in North America. Russian olive, various willows, woody plants in the pea family, and many horticulturally and agriculturally significant members of the rose family are also reported as hosts in Asia (Table 1) (Michalski 1973, Wang 1992, Wood and Bright 1992, Bright and Skidmore 1997, 2002, Liu and Haack 2003). The occurrence of *S. schevyrewi* on apricot, cherry, peach, and plum trees in Asia is particularly troubling because of the similar tree species and varieties in the fruit-growing regions of North America. Another exotic species, the shothole borer, *Scolytus rugulosus* (Müller), is a long-established pest of rosaceous trees in North America (Wood and Bright 1992) and might compete with *S. schevyrewi* in these hosts. To date, in the United States, *S. schevyrewi* has been collected from four species of elm—*U. americana*, *U. pumila*, *U. thomasii* Sarg. (rock elm), and *U. procera* Salisb. (English elm)—but not from any other hosts noted in the Asian literature.

Life History

In China, *S. schevyrewi* emerges from overwintering sites in late April, with a peak in early May. Emerging adults feed on the phloem in crotches of tender twigs and later attack the trunk for reproduction. Females burrow under the bark and construct single, longitudinal vertical egg galleries about 4–6 cm long that lack a nuptial chamber. Males move about the bark surface searching for entrance holes and mate with multiple females at these entrances. During oviposition, females form egg niches on both sides of the gallery and place an egg in each; later they cover the egg with boring debris. Between 20 and 120 eggs are placed in the gallery, and females guard the egg gallery until death. Larvae feed in the phloem and construct individual larval galleries that extend perpendicularly away from the egg gallery, which later meander and may cross one another. Five larval instars have been observed. Mature larvae migrate to the outer bark, where pupal chambers are constructed (Wang 1992, Liu and Haack 2003).

Wang (1992) reported two to three generations per year of *S. schevyrewi* in China, with the mature larva as the overwintering stage. Brood from the first generation of *S. schevyrewi* complete develop-

Table 1. Reported host trees for the banded elm bark beetle, *Scolytus schevyrewi* in Asia and North America[a]

Scientific name	Common name	Family	Reference
Ulmus americana L.[b]	American elm	Ulmaceae	This study
U. carpinifolia Gleditsch	Smooth-leaved elm	Ulmaceae	Michalski 1973
U. davidiana Planchon	Japanese elm	Ulmaceae or var. *japonica* [= *U. japonica* (Rehd.) Sarg.]	Michalski 1973, Wang 1992
U. laevis Pallas	European white elm	Ulmaceae	Bright and Skidmore 1997
U. macrocarpa Hance	Big fruit elm	Ulmaceae	Li et al. 1987, Yang et al. 1988
U. minor Miller	Field elm	Ulmaceae	Bright and Skidmore 1997
U. propinqua (Koidz.)	Chalked bark elm	Ulmaceae	Li et al. 1987, Yang et al. 1988, Bright and Skidmore 2002
U. pumila Linnaeus[b]	Siberian elm	Ulmaceae	This study, Bright and Skidmore 1997
U. thomasii Sargent[b]	Rock elm	Ulmaceae	This study
U. procera Salisbury[b]	English elm	Ulmaceae	This study
Ulmus sp.	A Chinese elm	Ulmaceae	Michalski 1973
Caragana korshinskii Kom.	A pea shrub	Fabaceae	Michalski 1973
Caragana spp.	Pea shrub	Fabaceae	Michalski 1973, Bright and Skidmore 1997
Elaeagnus angustifolia L.	Russian olive	Elaeagnaceae	Bright and Skidmore 1997
Elaeagnus sp.	An oleaster	Elaeagnaceae	Michalski 1973
Salix babylonica L.	Weeping willow	Salicaceae	Michalski 1973
Salix spp.	Willows	Salicaceae	Wang 1992
Malus pumila Miller	Paradise apple	Rosaceae	Bright and Skidmore 2002
Prunus amygdalus Batsch	Almond	Rosaceae	Bright and Skidmore 2002
P. armeniaca var. *ansu* Maxim. (=*Armeniaca vulgaris*)	Apricot	Rosaceae	Michalski 1973, Bright and Skidmore 1997
P. germanica	Unknown	Rosaceae	Bright and Skidmore 2002
P. glandulosa Thunb.	Flowering almond	Rosaceae	Bright and Skidmore 2002
P. padus L.	European bird cherry	Rosaceae	Michalski 1973
P. persica (L.) Batsch (=*Persica vulgaris* Mill.)	Peach	Rosaceae	Michalski 1973, Bright and Skidmore 1997
P. pseudocerasus Lindl.	A cherry	Rosaceae	Michalski 1973
P. salicina Lindl.	Santa Rosa plum	Rosaceae	Michalski 1973
P. yedoensis Matsum.	Yoshino cherry	Rosaceae	Michalski 1973
Pyrus X *bretschneideri* Rehder	Chinese white pear	Rosaceae	Bright and Skidmore 2002
Pyrus sp.	Pear	Rosaceae	Wood and Bright 1992

[a]Nomenclature for host trees is based on Knight (1969), Richens (1983), Newsholme (1992), and Jackson (2003).
[b]North American hosts.

ment by July and a second flight period begins that peaks in early July and is complete by late July. Most offspring from the second generation construct overwintering sites, but a small proportion continue developing to complete a third generation (Wang 1992, Liu and Haack 2003). The number of annual generations for *S. schevyrewi* in the United States has yet to be determined. In North America, *S. multistriatus* has one to two generations per year and sometimes a partial third and also overwinters as a fully mature larva in the bark. Adult emergence begins at any time between mid-March to late May, with peak flights and the occurrence of the second generation varying accordingly (Blackman 1950, Brown 1965, Brown and Eads 1966, Bright and Stark 1973). The timing of the flight periods is influenced by latitude (Drooz 1985). Although two generations of *S. multistriatus* appear most common, adults are usually present from May to September because the adults have an extended ovipositional period (Metcalf et al. 1962).

To initiate life history studies of *S. schevyrewi* in Fort Collins, naturally infested logs were collected on 27 June 2003. These logs were colonized at the time of collection and sampled on 10, 23, and 31 July. We first observed brood adults on 23 July, indicating the completion of the life cycle from egg to adult in less than 30 days (Figs. 5, 6). These logs were maintained in a wood shed that moderated the temperature regime under which the insects were developing. Completion of the life cycle under field conditions may take

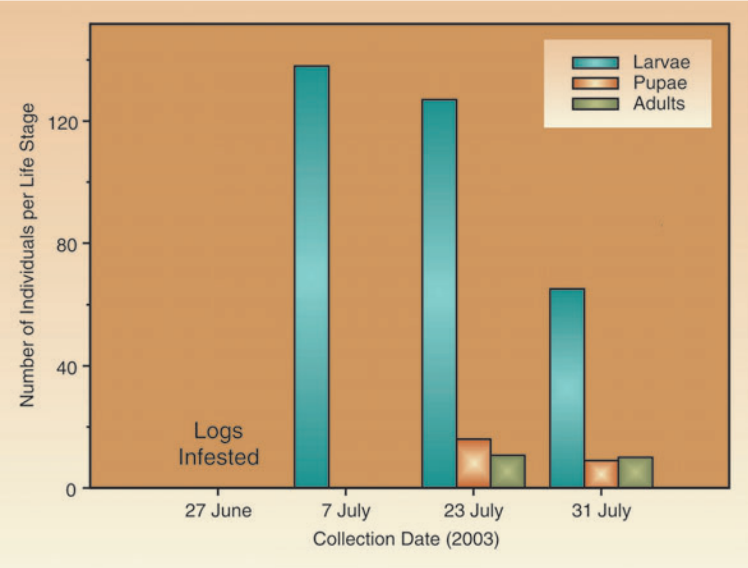

Fig. 5. Life stages of *Scolytus schevyrewi* at different dates from naturally infested logs collected 27 June 2003, Fort Collins, CO.

longer because environmental conditions may be less favorable. Reports on the time needed for *S. multistriatus* to complete development to the adult stage in North America are somewhat variable: 45–60 days (Blackman 1950), 35–40 days (Drooz 1985), and 2 months in Colorado (Cranshaw et al. 1993). Undoubtedly, this variation results in part from different environmental conditions, yet the time required for *S. multistriatus* to complete the life cycle approximates the 40–45 days reported by Wang (1992) for *S. schevyrewi* in China.

Although natural enemies of *S. schevyrewi* have been rare from our Fort Collins rearings so far, we have collected one parasitoid, identified by G. Gibson (Agriculture Canada) as *Cheiropachus quadrum* (F.) (Hymenoptera: Pteromalidae). This pteromalid is the parasitoid that occurs most frequently with *S. multistriatus* in California (Hajek and Dahlsten 1985a, b) and has an extensive geographic distribution covering most of the United States, as well as Ontario and Quebec (Burks 1979).

Potential Impact and Dutch Elm Disease Transmission

Wang (1992) indicated that the severity of *S. schevyrewi* damage to elm in Asia is dependent on tree vigor; trees exhibiting normal growth sustained little damage, whereas weakened trees experienced severe damage. A similar scenario has been observed in North America with *S. multistriatus* (Chamberlin 1939, Blackman 1950, Metcalf et al. 1962, Brown and Eads 1966, Drooz 1985). In Asia, repeated attacks by *S. schevyrewi* on declining trees lead to tree death. Increased reproduction and survival of *S. schevyrewi* were observed in recently dead trees or fresh logs with intact bark and no sap flow. Barked logs in woodpiles, high stumps, and dead trees are good breeding material for *S. schevyrewi*; insects completing development in these sites can infest and damage surrounding live host trees (Wang 1992).

We have observed *S. schevyrewi*-caused mortality of large elms in Fort Collins, perhaps on drought-stressed trees (Fig. 7). City foresters in

Fig. 6. Photo of gallery and life stages of *Scolytus schevyrewi*: (A) boring dust on surface of log produced during female gallery construction; (B) egg galleries and larval mines in phloem; (C) later stage of colonization showing complete consumption of phloem by larvae; and (d) pupa in outer bark (photos by José Negrón).

Fort Collins have reported high populations of *S. schevyrewi* attacking elm trees. On one elm with flagging branches in the crown, we observed sap exudation (Fig. 7, inset) on the bark surface around nascent attacks of *S. schevyrewi* in the living portion of the branches, and mass attack along the main trunk with boring dust pushed to the outer bark surface.

The ultimate impact of *S. schevyrewi* in North America may be decided by its ecological interactions with *S. multistriatus*. In rearing studies from two batches of infested American elm logs collected in June 2003 in Fort Collins, we found that almost 99% of the emerging adults were *S. schevyrewi* (*S. schevyrewi*, 593 males: 696 females; *S. multistriatus*, 5 males: 11 females). The preponderance of *S. schevyrewi* may suggest displacement of *S. multistriatus* by *S. schevyrewi*. In contrast, infested logs of American and Siberian elm collected in August 2003 in Reno, NV, yielded only 0.29 and 11.4% *S. schevyrewi*, respectively (2,769 and 4,191 emerged adults of each species in each instance). These observations indicate that *S. multistriatus* and *S. schevyrewi* may be differentially adapted in Colorado vs. Nevada, or perhaps that *S. schevyrewi* is only newly associated with *S. multistriatus* in Nevada. The data from Nevada also suggest a tendency for *S. schevyrewi* to colonize Siberian elm over American elm.

A primary concern arising from the establishment of *S. schevyrewi* in North America is whether it may also serve as a vector of the DED fungi, *O. novo-ulmi* or *O. ulmi* (Buisman) Nannf., and whether it may be more efficient than *S. multistriatus*. The DED–bark beetle complex has had a devastating effect by killing between 50 and 75% of the elm population that existed in northeastern North America (Bloomfield 1979; R. Hauer, University of Wisconsin-Stevens Point, personal communication) before the advent of the disease in the 1930s (Tainter and Baker 1996). Nonetheless, through natural regeneration, planting of resistant varieties, and good sanitation practices, elm continues to be an important urban tree, particularly in the Upper Midwest, the Great Plains, the Intermountain West, and California (R. Hauer, University of Wisconsin-Stevens Point, personal communication, McPherson et al. 2004). In 2003, in Fort Collins, 27 elm trees were removed; of these 24 were confirmed with DED, and the other 3 appeared to have died exclusively from attacks by *S. schevyrewi* (R. Zentz, Forestry Division, City of Fort Collins, personal communication).

In a preliminary study in 2003 to see whether *S. schevyrewi* carries spores of an Asian relative of the DED pathogen, isolations were made from emerging adults collected in Fort Collins and Lakewood, from trees without DED symptoms. No *Ophiostoma* spp. were recovered from these adults (T. C. Harrington, Iowa State University, and W. R. Jacobi, Colorado State University, personal communications). However, in 2004, isolations from *S. schevyrewi* collected from logs cut from trees with obvious DED symptoms in Colorado Springs and Denver, Colorado, yielded *O. novo-ulmi*. Similar percentages of adult *S. schevyrewi* and *S. multistriatus* carried the pathogen (in some cases >80% of the sampled beetles had spores of *O.*

Fig. 7. Large American elm, *Ulmus americana*, colonized by *Scolytus schevyrewi*. Approximate diameter at breast height was 160 cm (63 in.) to 175.3 cm (69 in.); the tree also had *Scolytus multistriatus* galleries at base. Tree was dead and removed soon after this photo was taken. Branches from another tree under attack by *S. schevyrewi* had yellowish sap flow in response to injury by the beetles (inset). (photo by José Negrón).

novo-ulmi) (Harrington and Jacobi, personal communications). *Ophiostoma ulmi* was not detected in the analyses from *S. schevyrewi*. Additional studies of this aspect of the ecology of *S. schevyrewi* are in progress.

Chemical Ecology

Host selection by *Scolytus* (Geoffroy) spp. involves long-distance (Peacock et al. 1971, 1984; Švihra and Koehler 1981; Millar et al. 1986) and short-range (Loschiavo et al. 1963, Baker and Norris 1968) chemical cues from the host. Unlike many other bark beetles, the role of one type of short-range signal (feeding stimulants) in host selection by *S. multistriatus* and other *Scolytus* spp. is understood to the extent that the chemical structures of the stimulants have been isolated and identified from host bark (Doskotch et al. 1973, Levy et al. 1974).

Chemically guided aggregation has been documented in several *Scolytus* spp., but the source of the semiochemicals ranges from host compounds alone (e.g., *S. ventralis* LeConte; Macías-Sámano et al. 1998a, b), to female-produced compounds alone (e.g., *S. amygdali* Guerin-Meneville; Ben-Yehuda et al. 2002), to combinations of female-produced and host compounds (e.g., *S. multistriatus*; Gore et al. 1977, Blight et al. 1983, Peacock et al. 1984), and to combinations of male-produced and host compounds (e.g., *Scolytus scolytus* (F.); Blight et al. 1979a,b,c; 1983). In the species that produce pheromones, the two most frequently encountered pheromone components are 4-methyl-3-heptanol and multistriatin (Fig. 8) (Mori 1974, 1977; Pearce et al. 1976; Lanier et al. 1976; Blight et al. 1979b, 1983; Vrkočová et al. 2003). In *S. amygdali*, female-produced 4-methyl-3-hexanol is also part of the attractant (Ben-Yehuda et al. 2002).

Among the *Scolytus*, the best understood aggregation pheromone system is that of *S. multistriatus* (Pearce et al. 1975). After feeding in branches and twig crotches, *S. multistriatus* females select a breeding site in dead elm phloem and release beetle-produced (–)-*threo*-4-methyl-3-heptanol and (–)-α-multistriatin . These pheromone components, combined with (–)-α-cubebene (released from the injured elm tissue), attract males and additional females (Peacock et al. 1971); the arriving females then initiate gallery construction.

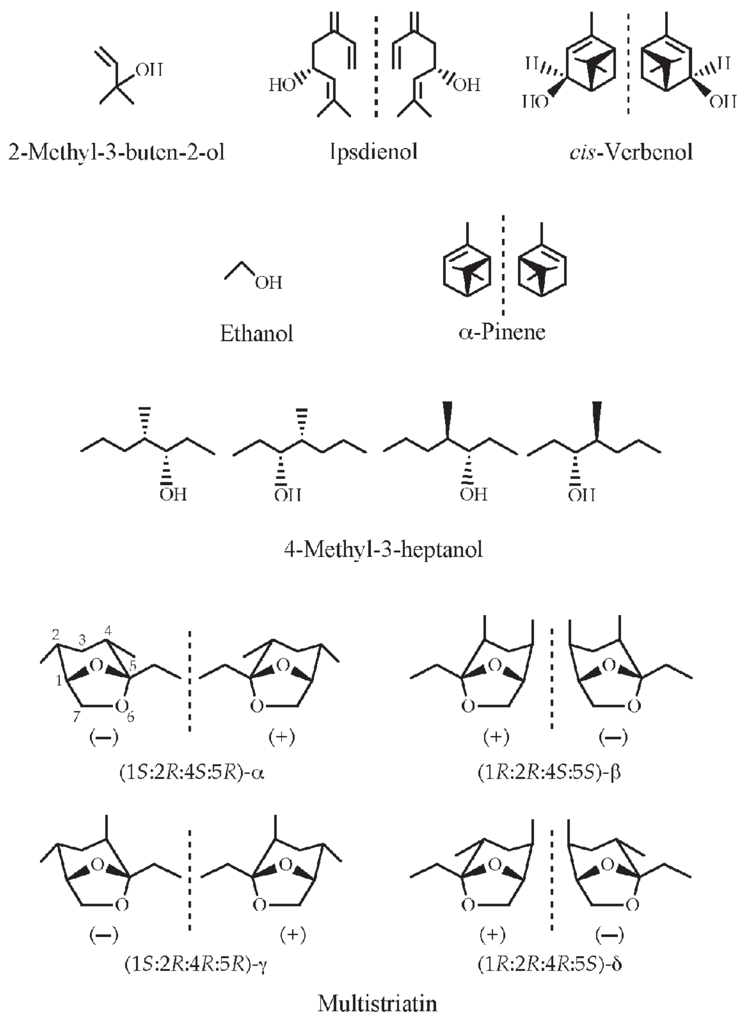

Fig. 8. Structures of semiochemicals used in detection surveys and field experiments of the flight behavior of *Scolytus schevyrewi*.

The chemical ecology of *S. schevyrewi* has not been studied in Asia. In 2003, in the United States, *S. schevyrewi* responded in flight during detection surveys to ultra-high release (UHR) ethanol (275 mg/day at 20 °C, Phero Tech), UHR ethanol plus UHR α-pinene (2 g/day at 20 °C, Phero Tech), and to the *I. typographus* lure comprising racemic ipsdienol (0.2 mg/day, PVC bubble cap), (–)-*cis*-verbenol (0.3 to 0.6 mg /day, PVC bubble cap), and 2-methyl-3-buten-2-ol (17-19 mg/day, pouch) (all at 20 °C, Phero Tech) (Fig. 8). Later, *S. schevyrewi* also was attracted to survey traps baited with Multilure (Patrick W. McPherren, USDA APHIS, Colorado), which is a complex mixture of hexanol, hexanal, and sesquiterpenes including cubebene (all from cubeb oil), semi-pure (–)-multistriatin, and racemic *erythro*- and *threo*-4-methyl-3-heptanol (released from two 400 µl centrifuge tubes at 0.3 mg/day at 20 °C, Phero Tech).

Between 17 June and 17 November 2003, we monitored the effects of various commercially available semiochemicals on the flight responses of *S. schevyrewi* and *S. multistriatus* on the grounds of the Denver Federal Center in Lakewood. Treatments included an unbaited trap and traps baited with Multilure, the *Ips typographus* pheromone, racemic *erythro*- and *threo*-4-methyl-3-heptanol, and 2-methyl-3-buten-2-ol. *Scolytus* spp. were captured in flight between 17 June and 28 October. Our data indicate elevated catches of *S. schevyrewi* from mid-July to mid-August and a peak flight period for *S. multistriatus* in mid-August (Fig. 9). We likely sampled the second generation of both species.

Of the *Scolytus* spp. trapped between 30 June and 2 September, 90% percent were *S. schevyrewi*. An analysis of the trap catch data during this time for *S. schevyrewi* showed a significant treatment of effects ($P = 0.0245$). Higher catches of *S. schevyrewi* and *S. multistriatus* were made with Multilure (Fig. 10). There was no significant difference between

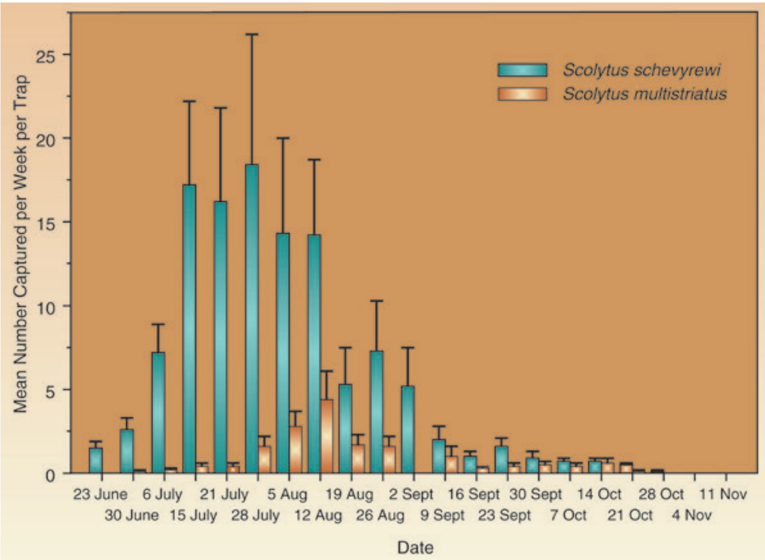

Fig. 9. Mean (±SE) weekly catches per trap of *Scolytus schevyrewi and Scolytus multistriatus* in Lakewood, CO, 17 June–17 November 2003. In total, 4,671 specimens of *Scolytus schevyrewi* and 653 specimens of *Scolytus multistriatus* were trapped in response to four semiochemical treatments and an unbaited trap. Flight ceased during the week of 21–28 October. Data from all treatments in each of eight blocks were pooled, and a mean was calculated across the blocks by week.

the responses of *S. schevyrewi* to Multilure or 2-methyl-3-buten-2-ol. *Scolytus schevyrewi* was also trapped in all other treatments, including the unbaited control traps. The non-specific response of *S. schevyrewi* in this experiment may reflect an aggregation pheromone blend that includes components of Multilure and the *I. typographus* bait. Alternatively, at this study site, we observed several small *U. pumila* trees under attack by *S. schevyrewi* in the vicinity of some of our monitoring locations, and it is possible that the population density of *S. schevyrewi* at this site was so high that beetles were caught in traps with normally unattractive baits. *Scolytus multistriatus* was much more selective in its response to treatments than *S. schevyrewi*; only Multilure attracted *S.*

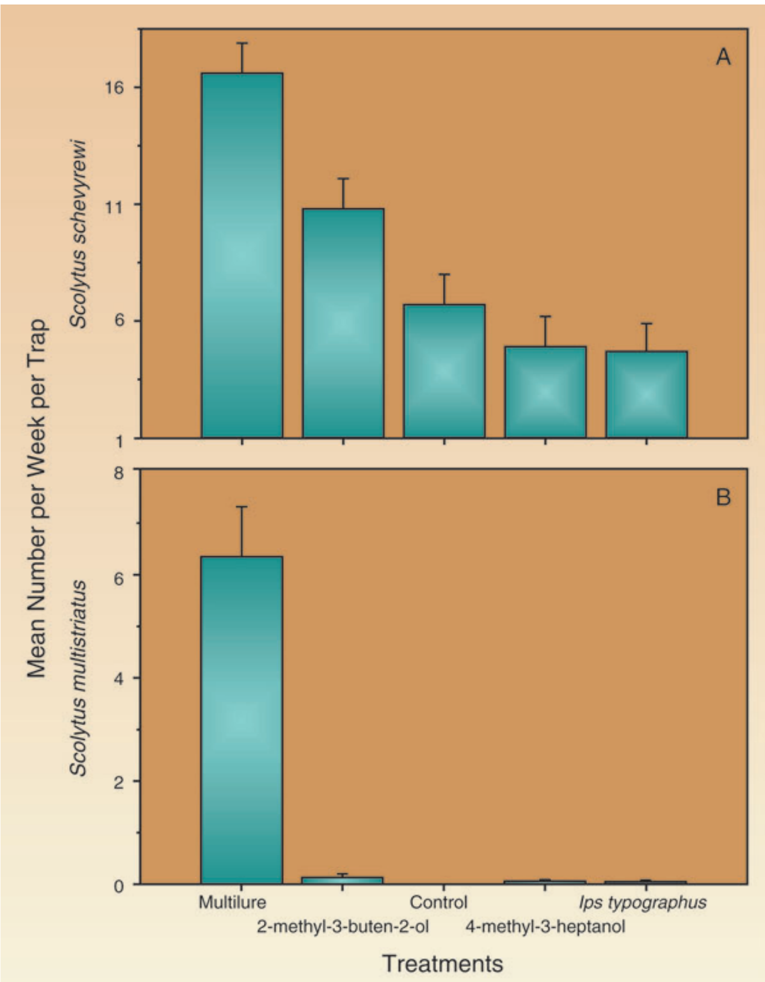

Fig. 10. Response of (A) *Scolytus schevyrewi* and (B) *S. multistriatus* to four semiochemical treatments and an unbaited trap in Lakewood, CO, 30 June–2 September 2003. Flight response to baited, 12-unit Lindgren funnel traps (8 replicates; each replicate includes one trap for each of five treatments; replicates separated by 100 to 300 m; traps within replicates separated by 25 m). Traps were emptied weekly and re-randomized every 2 weeks. Baits were replaced every four weeks. Multilure (see text) consisted of two 400 µl Eppendorf polyvial release devices (Phero Tech, Delta, BC); the *Ips typographus* lure consisted of 2-methyl-3-buten-2-ol released from a polyethylene pouch at 21 mg/day; *cis*-verbenol released from a polyethylene pouch at 0.5 mg/day; and racemic ipsdienol released from a 400 µl polyethylene vial at 0.15 mg/day, all release rates measured at 20°C (IPM Technologies, Portland, OR); racemic *erythro*- and *threo*-4-methyl-3-heptanol was released from a 400 µl Eppendorf polyvial (Phero Tech), 2-methyl-3-buten-2-ol was released from a polyethylene pouch at 21 mg/day (IPM Technologies). Soapy water served as the collection fluid in the trap cups. Data were analyzed by ANOVA using PROC GENMOD and pairwise comparisons of least square means adjusted with a Bonferroni correction ($\alpha = 0.05$) (SAS 1999).

multistriatus. No formal analysis was conducted for *S. multistriatus* because a high number of zero catches were problematic.

Because *S. schevyrewi* responded to Multilure and to 2-methyl-3-buten-2-ol, monitoring or detection efforts for may be conducted with either attractant. 2-methyl-3-buten-2-ol attracted almost exclusively *S. schevyrewi*, so in areas where *S. multistriatus* is known or suspected to occur in high numbers, the use of 2-methyl-3-buten-2-ol may be advantageous as it may require less effort to process samples. For instance, one sample submitted from the Rapid Detection and Response Pilot Project contained 16 *S. schevyrewi* and about 16,000 *S. multistriatus*. Cost is not a major factor in choosing between the two attractants; both products range from $3.00 to $5.00 per unit depending on the vendor.

An aggregation pheromone attractant for *S. schevyrewi* would be a valuable tool for effectively detecting and monitoring the beetle throughout North America and for monitoring populations. For example, in 1979, an earlier formulation of Multilure (not the commercial product) was used to detect the first occurrence of *S. multistriatus* in Winnipeg, Manitoba, at the far extremes of its likely distribution (Buth and Ellis 1981). Lanier et al. (1976) describe several other examples of using this earlier formulation of Multilure for survey and detection of *S. multistriatus* in North America, Australia, and Europe.

Summary and Future Plans

It is premature to accurately portray the potential impact that this introduced insect will have in the United States, but it could be significant. We have begun to examine various aspects of the biology and ecology of *S. schevyrewi*, including its life history, potential to vector DED fungi, and chemical ecology. Pressing and interesting questions that remain include the role of natural enemies in population regulation; the potential to attack non-elm hosts in North America (particularly *Prunus* spp. and *Salix* spp.); interactions with *S. multistriatus*; potential to kill trees with or without DED fungi; and identifying its point of entry and pathway into the United States. Application of molecular genetic analyses to the U.S. populations of *S. schevyrewi* may provide clues to its point of entry and direction of spread. Discovery and development of an aggregation pheromone should lead to better detection methods and possibly to the discovery and optimization of interruptant semiochemicals as management tools for *S. schevyrewi*. These and many other research questions remain, so it is important to continue to expand our efforts to develop appropriate management strategies to protect one of our most beautiful and valuable shade trees.

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