Nonindigenous forest insects continue to invade Canada, the United States, and other countries, adversely affecting ecosystems, industries, and private landowners. The use of trade names and identification of firms or corporations does not constitute an official endorsement or approval by the United States Government or the Canadian Government of any product or service to the exclusion of others that may be suitable. Funding for this research was provided by the USDA Forest Service, in part by a grant (RS–2006-01) from the Special Technology and Development Program (STDP). The USDA is an equal opportunity provider and employer.

ABSTRACT In 2007–2008, we examined the flight responses of Monochamus titillator (F.) complex [M. titillator, Monochamus carolinensis (Olivier), and any possible hybrids], Monochamus scutellatus (Say), Monochamus clamator (LeConte), Monochamus obtusus Casey, and Monochamus mutator LeConte (Coleoptera: Cerambycidae) to multiple-funnel traps baited with and without host volatiles and bark beetle pheromones. Experiments were conducted in mature pine (Pinus) stands in Alberta (Canada), and Arkansas, Arizona, California, Florida, Idaho, Michigan, Montana, New Hampshire, North Carolina, Ohio, Oregon, Tennessee, Utah, and Wisconsin (United States). At each location, traps were deployed in 10 replicate blocks of four traps per block. The trap treatments were: 1) blank control; 2) ipsenol and ipsdienol; 3) ethanol and α-pinene; and 4) a quaternary blend of ipsenol, ipsdienol, ethanol, and α-pinene. All five species or species complex of Monochamus preferred traps baited with the quaternary blend over all other treatments. The consistency of these results across such a large geographic area suggests that similar selection pressures may be acting on Monochamus spp. in pine forests, regardless of variation in stand composition and climatic conditions. Our results suggest that multiple-funnel traps baited with the quaternary blend of ipsenol, ipsdienol, ethanol, and α-pinene may be highly effective for monitoring various Monochamus spp. in pine forests of North America, and may have utility in trapping and detection programs in North America and overseas.

KEY WORDS α-pinene, ethanol, ipsenol, ipsdienol, kairomone
of large-diameter holes and tunnels (Cerezke 1977, Valentsgoed 1991). Larval feeding by *Monochamus* spp. can also result in significant levels of tree mortality. For example, Fettig et al. (2008) reported that cerambycids contributed directly to tree mortality in fire-injured trees in California.

The impact from sawyer beetles to forest industries in the United States is high, due largely to export restrictions of forestry products associated with the pine wood nematode, *Bursaphelenchus xylophilus* (Steiner and Buhrer) Nickel (Tylenchida: Aphenlenchoideidae) (Dwinell 1997, Webster 2003). The pine wood nematode, vectored by *Monochamus* spp., is endemic to North America and a major threat to coniferous forests around the world by causing a fatal wilting disease in some species of pines (Wingfield et al. 1982, Limit 1988, Evans et al. 1996). Pine forests in Japan experienced widespread damage and losses due to because of pine wilt disease after the introduction of pine wood nematode into Japan before 1905, with infestations affecting >28% of their pine forests in 2000 alone (Mamiya 2003). Pine wood nematodes have also been introduced into Taiwan, South Korea, and China (Evans et al. 1996). By 2000, >20 million pine trees had died from pine wilt disease over an area of 75,000 ha in China, since discovery of pine wood nematodes there in 1982 (Yang 2003). In 1999, pine wood nematodes were discovered in Portugal (Vicente et al. 2012).

Detection of pine wood nematodes in export wood products, such as pine chips and softwood lumber from the United States, has resulted in quarantine restrictions on the export of North American wood products (Bolla and Wood 2003). European countries stopped importation of pine wood chips from the United States in 1988 and currently require extensive treatments for solid wood products before importation, to ensure the lack of both pine wood nematode and sawyer beetles (Bolla and Wood 2003, Dwinell 2004).

There are eight recognized species of *Monochamus* in North America (Monné and Bezark 2012). *Monochamus carolinensis* (Olivier), *Monochamus marmorator* Kirby, *Monochamus notatus* (Drury), and *M. titillator* are found throughout eastern North America, whereas *Monochamus clarator* (LeConte) and *Monochamus obtusus* (Casey) are found in western North America. *M. scutellatus* is transcontinental in distribution and *Monochamus mutator* LeConte is found primarily in central Canada. The hosts for all species, except *M. marmorator*, include pines (*Pinus* spp.) (Furniss and Carolin 1980, USDA–FS 1985, Lingafelter 2007). Most of the pine species of sawyer beetles are known to vector the pine wood nematode (Evans et al. 1996).


In the southeastern United States, traps baited with a quaternary blend of two host volatiles, ethanol and α-pinene, and two bark beetle pheromones, ipsenol and ipsdienol, resulted in greater catches of *M. titillator–M. carolinensis* complex (see explanation in Methods) and *M. scutellatus* than traps baited solely with the host blend or bark beetle pheromones (Miller et al. 2011). Similarly, Allison et al. (2003) found that the same quaternary blend was attractive to *M. scutellatus* and *M. clamator* in British Columbia, Canada. Therefore, our objective was to determine the attractiveness of this quaternary blend to various species of *Monochamus* over a broad geographic range in Canada and the United States.

**Methods and Materials**

In 2007–2008, we conducted separate trapping experiments in stands of mature pine at each of 16 locations in Canada and the United States, using the same randomized complete block design (Table 1). At each location, we deployed 40 multiple-funnel traps (Contech Enterprises Inc., Victoria, BC, Canada, or Synergy Semiochemicals Corp., Burnaby, BC, Canada, for any given location) set in 10 replicate blocks (*n* = 10) of four traps per block. The number of blocks was reduced to nine in Montana (*n* = 9) owing to the disappearance of one trap early in the study. Sixteen-unit traps were used in California, whereas 12-unit traps were used in Michigan, New Hampshire, Ohio, Utah, and Wisconsin, and 8-unit traps were used at the remaining locations. Traps were spaced 10–25 m apart within blocks, with replicate blocks spaced ≥15 m apart. Each trap was suspended between trees by rope or on metal conduit stands such that each trap was ≥2 m from any tree and the bottom of each trap was 0.5–1.0 m above ground level. At each location, traps were deployed during the summer months for a period of ~12 wk (Table 1).

Each collection cup contained 150–200 ml of antifreeze solution as a killing and preservation agent (Miller and Duerr 2008). Catches were collected every 2–3 wk with new antifreeze solution added on each occasion. The following brands of antifreeze solutions were used in the trapping studies (Table 1): 1) Prestone Low Tox Antifreeze, Prestone Products Corp., Danbury, CT; 2) Splash RV & Marine Antifreeze, Fox Packaging Inc., St. Paul, MN; 3) Zecol RV Antifreeze, Zecol Products, Hamel, MN; 4) Arctic Ban Antifreeze,
at 25–28°C the rate of ethanol from ethanol UHR pouches was 0.6 g/d.

Lease (UHR) plastic pouch lures containing either propylene glycol in the other brands ranged from 6 to 20%. Inadvertently, Arctic Ban was used briefly at the beginning of the trapping period in Montana and at the end of the trapping period in California. The concentrations of propylene glycol in the other brands ranged from 6 to 37%, each with no ethanol content (verified by examination of product labels and associated Material Safety Data Sheets).

Contech Enterprises Inc. supplied ultra-high-release (UHR) plastic pouch lures containing either ethanol (150 ml) or α-pinene (200 ml). The enantiomeric purity of α-pinene was >95% (–). The release rate of ethanol from ethanol UHR pouches was 0.6 g/d at 25–28°C, whereas α-pinene was released at 2–6 g/d from α-pinene UHR pouches at 25–28°C (determined by weight loss). Bubble-cap lures containing either racemic ipsenol or racemic ipsdienol [chemical purities >95%, enantiomeric composition 50:50 (+)/(−)] were obtained from ConTech Enterprises Inc. in 2007 and Synergy Semiochemicals Corp. in 2008. Ipsenol and ipsdienol were released from bubblecaps at 0.1–0.3 mg/d at 22–25°C (Contech Enterprises Inc., Synergy Semiochemical Corp.).

One of the following four treatments was allocated to each of the four traps within each block: 1) blank control, 2) ethanol + α-pinene, 3) ipsenol + ipsdienol, and 4) ethanol + α-pinene + ipsenol + ipsdienol. Species identifications, taxonomic names, and authors were determined using Lingafelter (2007) and ITIS (2013). We found separation of *M. carolinensis* from *M. titillator* to be difficult and inconsistent, using characters noted by Linsley and Chemsak (1984) and Lingafelter (2007), particularly those concerning the apical spines of the elytra. The two species are broadly sympatric in pine stands throughout eastern North America (Linsley and Chemsak 1984). Hopping (1921) noted that “In long series every variation in size, maculation and reduction of the spine into a blunt form may be found” and had placed *M. carolinensis* as a synonym of *M. titillator*. Therefore, we designated *M. titillator*, *M. carolinensis*, and any possible hybrids as *M. titillator* complex. Voucher specimens of all species were deposited in the Entomology Collection, Museum of Natural History, University of Georgia (Athens, GA).

Trap catch data were transformed by ln(Y + 1) to ensure homoscedasticity (Pepper et al. 1997) for locations where sufficient numbers of individuals (N ≥ 50) were captured for each species. Data for blank controls were omitted from analyses when means and

Table 1. Locations, predominant pine species, brands of antifreeze, and trapping dates for each of 16 experiments in which the flight responses of *Monochamus* spp. to multiple-funnel traps baited with host volatiles and bark beetle pheromones were determined.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Location</th>
<th>Coordinates</th>
<th>Predominant pine species</th>
<th>Antifreeze brand*</th>
<th>Trapping dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lac La Biche, AB</td>
<td>55.091N, 111.987W</td>
<td><em>Pinus banksiana</em> Lamb.</td>
<td>Prestone Low Tox</td>
<td>19 June-11 Sept. 2007</td>
</tr>
<tr>
<td>3</td>
<td>Kaibab NF, Coconino Co., AZ</td>
<td>35.381N, 111.901W</td>
<td><em>Pinus ponderosa</em> Doug.</td>
<td>Splash</td>
<td>6 June-29 Aug. 2008</td>
</tr>
<tr>
<td>4</td>
<td>Ochita NF, Yuell Co., AR</td>
<td>35.040N, 93.668W</td>
<td><em>Pinus taeda</em> L.</td>
<td>Splash</td>
<td>23 June-17 Sept. 2008</td>
</tr>
<tr>
<td>5</td>
<td>Tahoe NF, Nevada Co., CA</td>
<td>39.395N, 120.156W</td>
<td><em>P. ponderosa</em> and <em>Pinus jeffreyi</em> Balf.</td>
<td>Zecol and Arctic Ban</td>
<td>18 May-10 Aug. 2007</td>
</tr>
<tr>
<td>6</td>
<td>Austin Cary Memorial Forest, Alachua Co., FL</td>
<td>29.742N, 82.201W</td>
<td><em>P. taeda</em> L.</td>
<td>Easy Going</td>
<td>23 April-16 July 2008</td>
</tr>
<tr>
<td>7</td>
<td>Idaho Panhandle NF, Bonner Co., ID</td>
<td>48.000N, 116.733W</td>
<td><em>P. ponderosa</em> and <em>P. contorta</em></td>
<td>Splash</td>
<td>3 June-2 Sept. 2008</td>
</tr>
<tr>
<td>8</td>
<td>Kellogg Research Forest, Kalamazoo Co., MI</td>
<td>42.358N, 85.375W</td>
<td><em>Pinus resinosa</em> Sol. ex Aiten</td>
<td>SuperTech</td>
<td>17 May-7 Sept. 2008</td>
</tr>
<tr>
<td>9</td>
<td>Beaverhead-Deerlodge NF, Beaverhead Co., MT</td>
<td>45.570N, 112.940W</td>
<td><em>P. contorta</em></td>
<td>Arctic Ban and Splash</td>
<td>12 June-5 Sept. 2007</td>
</tr>
<tr>
<td>10</td>
<td>Bear Brook State Park, Merrimack Co., NH</td>
<td>43.139N, 71.367W</td>
<td><em>Pinus strobus</em> L.</td>
<td>Preston Low Tox</td>
<td>15 June-20 Sept. 2007</td>
</tr>
<tr>
<td>13</td>
<td>Deschutes NF, Jefferson Co., OR</td>
<td>44.400N, 121.650W</td>
<td><em>P. ponderosae</em></td>
<td>20/10</td>
<td>14 May-6 Aug. 2008</td>
</tr>
<tr>
<td>16</td>
<td>La Crosse County Forest, La Crosse Co., WI</td>
<td>44.059N, 91.073W</td>
<td><em>P. resinosa</em></td>
<td>Peak</td>
<td>10 June-2 Sept. 2008</td>
</tr>
</tbody>
</table>

*See text for names and locations of manufacturers.
variances for a location were both zero because of a lack of homoscedasticity in using such data in statistical analyses (Reeve and Strom 2004). Before proceeding to analysis of variance (ANOVA), normality and homoscedasticity were verified using the Kolmogorov–Smirnov and equal variance tests, respectively, with the SigmaStat (version 3.01) statistical package (SYSTAT Software Inc., Point Richmond, CA). To determine treatment effects across locations, data were subjected to ANOVA with the SYSTAT statistical package (SYSTAT Software Inc.) by using the following model components: 1) replicate (nested within location), 2) location, 3) treatment, and 4) location × treatment. To determine treatment effects within locations, trap catch data for each location were subjected to ANOVA with the SigmaStat package by using the following model components: 1) replicate and 2) treatment. The Holm–Sidak multiple comparison procedure (Glantz 2005) was used to compare means within a location for each species exhibiting a significant treatment effect ($\alpha = 0.05$).

**Results**

We collected sufficient numbers of individuals ($N \geq 50$) to conduct statistical analyses on all but two species of *Monochamus* in Canada and the United States. *M. notatus* was captured in small numbers (<15 at any location), whereas *M. marmorator* was not captured at any location. *M. titillator* complex was captured in sufficient numbers for analyses at seven locations ranging from Florida to Arkansas and Wisconsin (Fig. 1), with a significant treatment effect on trap catches across the locations (Table 2). The blank treatments were omitted from the analysis because mean catch and variance were zero in Florida, Michigan, and Tennessee (Fig. 1B, C, F). At all seven locations, catches of *M. titillator* complex were highest in traps baited with the quaternary blend (Fig. 1). Although there was a significant interaction between location and the three treatments (Table 2), traps baited with the binary blend of ipsenol and ipsdienol outperformed those baited with the binary blend of ethanol and $\alpha$-pinene at all seven locations (Fig. 1). We caught seven *M. titillator* complex in New Hampshire, too few for analysis. *M. titillator* complex was not captured at the other locations.

There was a significant treatment effect on catches of *M. scutellatus* in New Hampshire, Ohio, Utah, and Wisconsin (Table 2). At all four locations, catches of *M. scutellatus* were highest in traps baited with the quaternary blend (Fig. 2). We found a significant interaction between location and treatments on trap catches (Table 2). Catches of *M. scutellatus* were greater in traps baited with ipsenol and ipsdienol than in traps baited with ethanol and $\alpha$-pinene in New Hampshire, Ohio, and Wisconsin, whereas there was no significant difference between these two treatments in Utah. We caught low numbers of *M. scutellatus* in Alberta in 2007 and 2008, and in Michigan, Montana, and Oregon ($N = 6, 8, 31, 15, and 4$, respectively), too few for analysis. *M. scutellatus* was not captured at the other locations.

We captured sufficient numbers of *M. clamator* for analyses in five locations, with a significant treatment effect and a significant interaction between location and treatment (Table 2). Traps baited with the quaternary blend outperformed the other treatments in Arizona, California, and Idaho (Fig. 3A-C). In Montana, catches of *M. clamator* in traps with the quaternary blend were greater than those in blank control traps, but not those baited with either binary blend (Fig. 3D). In Oregon, traps with the quaternary blend outperformed blank control traps and traps baited with ethanol and $\alpha$-pinene, but not those baited with
ipsenol and ipsdienol (Fig. 3E). Differences in the relative attractiveness of the two binary blends were evident among locations (Fig. 3). In Arizona, catches of *M. clamator* in traps baited with ethanol and α-pinene were greater than those baited with ipsenol and ipsdienol, whereas the opposite was true in California. There was no difference in catches of *M. clamator* between those baited with the two binary blends in the remaining locations. *M. clamator* was not captured at the other locations.

There was a significant treatment effect on catches of *M. obtusus* in Idaho and Oregon (Table 2). The blank treatments were omitted from the analysis because mean catch and variance were zero in Idaho (Fig. 4A). At both locations, traps baited with the quaternary blend caught more beetles than any of the other treatments (Fig. 4). There was a significant interaction between location and treatment on catches of *M. obtusus* (Table 2). Catches of beetles in traps baited with ipsenol and ipsdienol were greater than those in traps baited with ethanol and α-pinene in Oregon, but not in Idaho. We caught 12 *M. obtusus* in California, too few for analysis. *M. obtusus* was not captured at the other locations.

*M. mutator* was captured only in Alberta, but at two locations 175 km apart. There was a significant treatment effect on catches, but no significant interaction between location and treatment was observed (Table 2). The blank treatments were omitted from the analyses because mean catch and variance were zero at both locations (Fig. 5). Traps baited with the quaternary blend outperformed those with either of the binary blends.

### Table 2. Analysis of variance table for effects of treatment (T), location (L), treatment and location interaction (L × T), and replicate nested within location (R[L]) on catches of *M. titillator* complex, *M. scutellatus*, *M. clamator*, *M. obtusus*, and *M. mutator* in North America.

<table>
<thead>
<tr>
<th>Factor</th>
<th><em>M. titillator</em> complex</th>
<th><em>M. scutellatus</em></th>
<th><em>M. clamator</em></th>
<th><em>M. obtusus</em></th>
<th><em>M. mutator</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>df</td>
<td>F</td>
<td>P</td>
<td>df</td>
<td>F</td>
</tr>
<tr>
<td>T</td>
<td>2</td>
<td>408.27</td>
<td>&lt;0.01</td>
<td>3</td>
<td>86.46</td>
</tr>
<tr>
<td>L</td>
<td>6</td>
<td>210.83</td>
<td>&lt;0.01</td>
<td>3</td>
<td>69.04</td>
</tr>
<tr>
<td>T × L</td>
<td>12</td>
<td>9.01</td>
<td>&lt;0.01</td>
<td>9</td>
<td>12.24</td>
</tr>
<tr>
<td>R[L]</td>
<td>63</td>
<td>1.67</td>
<td>&lt;0.01</td>
<td>36</td>
<td>2.41</td>
</tr>
<tr>
<td>Error</td>
<td>126</td>
<td>108</td>
<td></td>
<td>132</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 2.** Mean (+SE) number of *Monochamus scutellatus* captured in multiple-funnel traps baited with ethanol + α-pinene (EA), ipsenol + ipsdienol (SD), and all four compounds (EA + SD) in New Hampshire (A), Ohio (B), Utah (C), and Wisconsin (D). At each location, means followed by the same letter are not significantly different at P = 0.05 (Holm–Sidak test). N = Total trap catch of *M. scutellatus* per location.

**Monochamus clamator**

<table>
<thead>
<tr>
<th>Location</th>
<th>Treatment</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona</td>
<td>Blank</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>EA</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>c</td>
</tr>
<tr>
<td></td>
<td>EA+SD</td>
<td>d</td>
</tr>
<tr>
<td>California</td>
<td>Blank</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>EA</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>b</td>
</tr>
<tr>
<td></td>
<td>EA+SD</td>
<td>c</td>
</tr>
</tbody>
</table>

**Fig. 3.** Mean (+SE) number of *Monochamus clamator* captured in multiple-funnel traps baited with ethanol + α-pinene (EA), ipsenol + ipsdienol (SD), and all four compounds (EA + SD) in Arizona (A), California (B), Idaho (C), Montana (D), and Oregon (E). At each location, means followed by the same letter are not significantly different at P = 0.05 (Holm–Sidak test). N = Total trap catch of *M. clamator* per location.
obtusus per location.

Means followed by the same letter are not significantly different at P = 0.05 (Holm–Sidak test). Treatment with an asterisk had zero catches.

Discussion

Catches of all five species or species complex of Monochamus were highest in traps baited with the quaternary blend over all other treatments (Figs. 1–5). The consistency of this result across such a large geographic area suggests that similar selection pressures may be acting on Monochamus spp. in pine forests, regardless of variation in forest composition and climatic conditions. Ethanol and α-pinene occur naturally in pine forests and are likely associated with host conditions favorable for feeding, mating, and oviposition by Monochamus spp. Monochamus spp. colonize stressed, dead, and dying trees (Furniss and Carolin 1980). Ethanol is produced by conifers that are temporarily stressed and by tissues in dead and dying trees (Kelsey 1994, 1996; Kelsey and Joseph 1998, 2003). The monoterpene α-pinene is a major constituent of the oleoresin of most pines (Mirov 1961, Smith 2000). In addition, adult sawyer beetles are relatively long-lived and feed on pine foliage and twigs throughout their breeding period. Selection should favor individuals that can locate quality forage, possibly indicated by the release of α-pinene from needles. The foliage of pines such as loblolly pine, Pinus taeda L., is rich in terpenes such as α-pinene (Schultz 1997). Selection should also favor attraction of beetles to α-pinene if it ensures that beetles are attracted to the same locations for mating. Therefore, selection for response to α-pinene and ethanol may be related to three biological functions that may, at times, occur at different locations: adult feeding, mating, and oviposition.

Ipsenol and ipsdienol occur naturally in pine forests. Throughout North America, engraver beetles, Ips De Geer spp., are typically the earliest invaders of certain types of host material, such as lightning-struck trees or recently downed live trees or limbs (Furniss and Carolin 1980, USDA–FS 1985), invading the phloem tissue and producing such pheromones as ipsenol and ipsdienol (Borden 1982; Smith et al. 1993; Allison et al. 2004, 2013). The additive effect of ipsenol and ipsdienol in attracting the M. titillator complex to ethanol and α-pinene likely reflects conditions with a higher likelihood of host suitability for oviposition and larval development (Miller et al. 2011). The same host material should be ideal for brood development by the M. titillator complex before further host deterioration.

Selection pressures may be similar in the chemical ecology of other species of Monochamus as well (Allison et al. 2004). Allison et al. (2001) reported a kairomonal response by four Monochamus spp. in Canada (M. clamator, M. scutellatus, M. notatus, and M. obtusus) to a blend of ipsenol, ipsdienol, 3-methyl-2-cyclohexenone, and frontalin. Further work confirmed ipsenol and ipsdienol increased the attraction of M. clamator and M. scutellatus to ethanol and α-pinene (Allison et al. 2003). In western North America, ipsdienol is produced by male western pine beetle, Dendroctonus brevicomis LeConte (Coleoptera: Curculionidae) (Byers 1982), during the latter stages of host colonization, and by sympatric Ips spp. (Byers 1989). In this context, ipsdienol may signal an increase in host suitability for the secondary pest Monochamus spp., as tree defensive mechanisms are sufficiently compromised by D. brevicomis attacks, but before substantial host deterioration has occurred.

The responses of Monochamus spp. to ipsenol and ipsdienol may also relate to an ecological role as facultative intraguild predators of bark beetles and associated species (Dodds et al. 2001, Schoeller et al. 2012). Foraging by larval M. titillator can have a significant impact on brood production of the southern pine beetle, Dendroctonus frontalis Zimmermann (Coulson et al. 1980), and the sixspined ips, Ips calligraphus (Germar) (Coleoptera: Curculionidae) (Miller 1986). In the laboratory, Dodds et al. (2001) reported high mortality of larval bark beetles from attacks or ingestion by larval M. carolinensis. Through DNA analyses, Schoeller et al. (2012) found that 9.6% of larval M. titillator collected in the wild tested positive for consumption of I. calligraphus and the eastern fivespined ips, Ips grandicollis (Eichhoff). Although the small southern pine engraver, Ips avulsus (Eichhoff), was present in significant numbers in phloem...
tissue of pine trees. Schoeller et al. (2012) were unable to assay its DNA presence in larval *M. titillator* owing to an inability to amplify primers for *I. avulsus* in larval tissues. The direct fitness benefit to larval *Monochamus* from ingestion of bark beetle larvae remains to be determined.

The addition of the *Monochamus* spp. pheromone monochamol may further enhance the efficacy of the quaternary blend for *Monochamus* spp. (Macias-Samano et al. 2012). There are 12 species of *Monochamus* native to Asia and Europe, none in the southern hemisphere (Evans et al. 1996, Sama 2002). After introductions of pine wood nematode into Asia and Portugal, *Monochamus alternatus* Hope and *Monochamus galloprovincialis* Olivier were found to vector the pine wood nematode in their respective regions (Mamiya 2003, Yang 2003, Vicente et al. 2012). Attraction to host odors is enhanced by pheromones such as ipsenol for *M. galloprovincialis* (Pajares et al. 2004, Ibeas et al. 2006) but not for *M. alternatus* (Fan et al. 2010). However, both species are attracted to monochamol (Pajares et al. 2010, Teale et al. 2011) as are a number of North American species (Allison et al. 2012, Fierke et al. 2012).

The use of a standardized single lure blend in a single trap rather than the use of separate traps with different lures in detection and survey programs could reduce expenses associated with national programs (Hanks et al. 2012). We suggest that traps baited with the quaternary blend of ipsenol, ipsdienol, ethanol, and α-pinene could be a useful detection tool at ports-of-call in countries outside of North America and at ports-of-departure and manufacturing sites within North America. This quaternary blend is an effective lure for five North American species or species complex of *Monochamus* within North America (Figs. 1–5) as well as other species of pine-inhabiting Cerambycidae in the southeastern United States, such as *Acanthocinus nodosus* (F.), *Acanthocinus obsoletus* (Olivier), *Rhagium inquisitor* (L.), *Astylopsis arcuata* (LeConte), and *Astylopsis sexguttata* (Say) (Allison et al. 2003, Miller et al. 2011).

Acknowledgments

For their assistance and permission to conduct these studies on their respective lands, we thank the staff at the following forests: Austin Cary Memorial Forest (FL), Bear Brook State Park (NH), Beaverhead-Deerlodge National Forest (MT), Blue Rock State Park (OH), Cherokee National Forest (TN), Deschutes National Forest (OR), Ft. Assiniboine Sandhills Wildland Park (AB), Kaibab National Forest (AZ), Kellogg Research Forest (MI), La Crosse County Forest (WI), Nantahala National Forest (NC), Ouachita National Forest (AR), Idaho Panhandle National Forest (ID), Tahoe National Forest (CA), and Uinta-Wasatch-Cache National Forest (UT). We thank the following people for organizational, field, and laboratory assistance: Allison Brec, Jarrett Bates, Justin Berg, Darren Blackford, Bob Borys, Stephen Burr, Tyler Carlee, Tina Ciarnitari, Chris Crowe, Chris Dabney, Thomas Davis, Valerie DeBlander, Don Duerr, Garrett Dubois, Laura Dunning, Jeff Eickwort, Larry Galligan, Geoff Gardner, Ken Gibson, Sam Green, Laurel Haavik, Jim Hammond, Josh Jones, Sandy Kegley, Matt McCall, Steve McKelvey, Ben Meyerson, Bob Murphy, Jason Neumann, Lee Pederson, Bob Rabaglia, Kendra Schotzko, Brytten Steed, Fred Stephen, and Daryl Williams. Sincere thanks to Jeremy Allison for his critical review of an earlier version of this manuscript.

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Received 31 January 2013; accepted 21 April 2013.