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Tomicus Piniperda (Coleoptera: Scolytidae) Reproduction and Behavior on Scotch Pine Christmas Trees Taken Indoors

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TOMICUS PINIPERDA (COLEOPTERA: SCOLYTIDAE) REPRODUCTION AND BEHAVIOR ON SCOTCH PINE CHRISTMAS TREES TAKEN INDOORS

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ABSTRACT

Tomicus piniperda, the pine shoot beetle, is an exotic insect that was first found in North America in 1992. A federal quarantine currently restricts movement of pine products, including Christmas trees, from infested to uninfested counties. We conducted a study to determine if *T. piniperda* would reproduce in Christmas trees that were cut and taken indoors during the Christmas season. Twelve Scotch pine, *Pinus sylvestris*, Christmas trees infested with overwintering *T. piniperda* beetles were cut in Indiana in early December 1993 and taken to Michigan. Four trees were dissected immediately, while the other 8 trees were taken indoors, placed in tree stands, and watered regularly. After 4 weeks indoors, 4 trees were dissected, and the other 4 were placed outdoors in Michigan for 7 weeks. Upon dissection, all overwintering sites occurred along the lower trunk within the first 40 cm of the soil line; 81% were found within 10 cm of the soil line. Adults collected from the 4 trees dissected in December produced viable progeny adults when placed on Scotch pine logs in the laboratory. Overwintering beetles became active and laid eggs in 4 of the 8 trees that had been taken indoors. All adults and progeny found in the 4 trees that had been placed outdoors for 7 weeks during cold January and February temperatures were dead. Overall, *T. piniperda* can become active and breed in Christmas trees that are cut and taken indoors in December. *Tomicus piniperda* survival in trees that are discarded outdoors at the end of the Christmas season will depend largely on the prevailing temperatures.

The pine shoot beetle [*Tomicus piniperda* (L.); Coleoptera: Scolytidae] was discovered in Ohio in July 1992 (Haack 1997, Haack and Kucera 1993, Haack et al. 1997). As of January 1997, established populations of this beetle have been found in 187 counties in 8 states in the United States and in 17 counties in Ontario, Canada (Fig. 1). This Eurasian scolytid appears to have arrived in the Great Lakes region on two separate occasions, probably on cargo ships that carried infested wood crating or dunnage (i.e., log braces) from Europe (Carter et al. 1996, Haack et al. 1997).

Considering *T. piniperda* as a potentially damaging pest of pines, in No-

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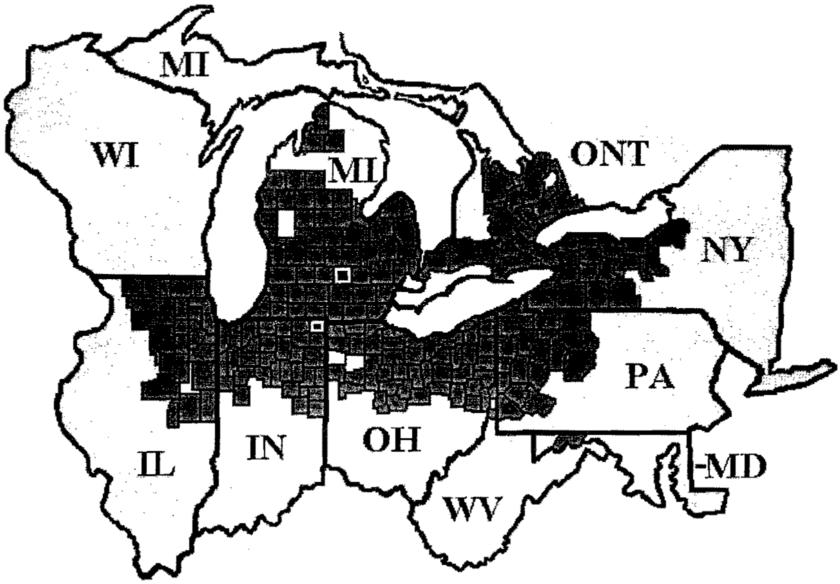

Figure 1. Known distribution of *T. piniperda*-infested counties in North America as of January 1997 (Source: USDA APHIS and Agriculture Canada). The two squares indicate the two counties (Steuben County, Indiana, and Ingham County, Michigan) where this study took place. Abbreviations are: IL = Illinois, IN = Indiana, MD = Maryland, MI = Michigan, NY = New York, OH = Ohio, ONT = Ontario, PA = Pennsylvania, WI = Wisconsin, and WV = West Virginia.

vember 1992 the United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) imposed a quarantine on the movement of pine from regulated (infested) counties to unregulated (uninfested) counties within the United States (Haack et al. 1997, USDA APHIS 1992). The quarantine regulated movement of pine logs or lumber with bark attached, pine nursery stock, and pine Christmas trees. Regulated pine material could be moved to areas outside the quarantine zone, but only after specific conditions were met. As currently written, the federal quarantine has zero tolerance for *T. piniperda*. Christmas trees are inspected as individual fields of trees. Fields can vary considerably in acreage. Finding a single beetle or its damage will prohibit all sales of pine Christmas trees from that particular infested field to areas outside the quarantine zone unless the trees are subjected to an approved cold-temperature or fumigation treatment (Haack et al. 1997, USDA APHIS 1992).

In 1997, a national *T. piniperda* compliance management program was initiated by USDA APHIS that allows growers in regulated areas to ship their trees to unregulated areas without inspection given that they agree to and strictly follow a series of management guidelines (USDA APHIS 1996, McCullough and Sadof 1996). It is felt that if all pest management steps are followed, then the resulting *T. piniperda* population will be so low as to pose little or no risk of spread through the movement of pine Christmas trees.

Therefore, starting in 1997, Christmas tree managers in regulated counties have the option to either enroll in the national *T. piniperda* compliance management program or subject their trees to inspection.

The Great Lakes region is a major area of Christmas tree production in the United States. More than 10 million trees are sold each year in this area, and about 75% of them are Scotch pine (*Pinus sylvestris* L.) (Dr. Melvin R. Koelling, Department of Forestry, Michigan State University, pers. comm.). Christmas trees from the Great Lakes region are sold throughout the United States, as well as in Mexico, the Caribbean region, and other countries.

Tomicus piniperda is a univoltine bark beetle (Bakke 1968, Haack and Lawrence 1995a, 1995b, Långström 1983). Adults overwinter in the outer bark at the base of live pine trees. Adults become active in early spring and fly to recently cut pine stumps and pine logs to breed. Progeny adults start emerging in early summer and then fly to the crowns of living pine trees where they conduct maturation feeding inside one or more shoots during the summer and early autumn. In autumn, soon after the first few nights of subfreezing temperatures, adults exit the shoots and move to overwintering sites. The adults apparently walk along branches to the tree trunk and then down to the base of the trunk where they tunnel into outer bark and spend the winter. All North American pines appear susceptible to *T. piniperda* attack (Haack and Lawrence 1997, Långström and Hellqvist 1985, Långström et al. 1995, Lawrence and Haack 1995, Sadof et al. 1994).

In the Great Lakes region, most Christmas trees are harvested from late October through December, when most *T. piniperda* adults are moving to or already in their overwintering sites near the base of the tree. If an infested pine Christmas tree is cut close to the ground, it is possible that overwintering beetles could be moved with that tree, and subsequently taken indoors by the buyer. What is the fate of such beetles? Will they emerge, fly, breed, shoot-feed, die, or remain in place? We designed a study to monitor *T. piniperda* behavior when infested trees are cut and taken indoors during the typical Christmas season.

MATERIALS AND METHODS

We selected 12 unpruned Scotch pine trees, 1.5–3 m tall, in a *T. piniperda*-infested Christmas tree plantation in northeastern Indiana near Orland, Steuben County, on 19 October 1993 (ca. 41° 45′ N Lat, 85° 10′ W Long; Fig. 1, Table 1). From pine trees other than the 12 test trees, we collected 230 *T. piniperda*-attacked shoots. To increase the chances that *T. piniperda* adults were still present in the shoots, we collected only attacked shoots that still had mostly green foliage. We have noted that attacked shoots with mostly yellow to brown foliage usually do not contain *T. piniperda* adults (Haack et al. unpublished data). We tied 15 shoots in the upper half of each of the 12 test trees. Each cut shoot was tied tightly to a living shoot of a test tree so that the two twigs touched for most of their common length. This was done so that emerging beetles could more easily walk along the branches towards their overwintering sites. In our laboratory on the Michigan State University campus in East Lansing, Ingham County, Michigan, we dissected the 50 remaining shoots to estimate the percentage of attacked green shoots that still contained *T. piniperda* adults on 19 October 1993.

On 2 December 1993, we harvested the 12 test trees. First, we collected the 15 shoots that had been tied to each tree and bagged them separately by tree. Then we removed the lower two whorls of branches from each tree to allow access to the trunk. All cut branches were inspected for *T. piniperda*

Table 1. Summary data for the 12 Scotch pine Christmas trees from Steuben County, Indiana, used in this study.

Tree No.	Trmt[1]	Approx. tree ht (cm)	Depth (cm)		Tree diam. at soil line (cm)	No. of shoots ≥3 mm[2]	No. of attacked shoots	No. of test shoots with potentially live beetles[3]	No. of potential adults[4]	No. of overwintering sites[5]
			Cut below soil line	Of duff layer						
1	Dec	150	4	3	10.6	912	2	15	17	15
2	Dec	240	4	5	12.1	652	6	15	21	25
3	Dec	270	5	10	12.2	585	14	15	29	33
4	Dec	165	5	5	15.6	1278	2	15	17	17
5	Jan	255	4	5	10.7	906	13	14	27	27
6	Jan	210	5	5	11.9	434	21	15	36	22
7	Jan	210	7	2	10.9	938	31	14	45	30
8	Jan	180	4	3	11.9	732	13	15	28	11
9	Feb	195	7	2	8.1	248	2	14	16	13
10	Feb	240	3	4	14.4	676	16	15	31	34
11	Feb	210	4	10	13.0	686	11	15	26	18
12	Feb	180	6	3	11.3	1513	12	15	27	6

[1] Treatments: Dec = trees dissected in the field in early December 1993; Jan = trees dissected in early January 1994 after being indoors for about 4 weeks; Feb = trees dissected in late February 1994 after being indoors for about 4 weeks and then outdoors in Michigan for about 7 weeks.
[2] Only current-year and 1-year-old shoots were counted.
[3] We placed 15 shoots on each tree. Where the value is 14, we found either a dead beetle or an aborted attack.
[4] Number of potential adults = sum of the number of naturally attacked shoots and the number of test shoots added to each tree that likely contained an adult beetle. This assumes one beetle per attacked shoot.
[5] Number of overwintering sites = the number of overwintering sites actually found on the trunk of each tree.

shoot-feeding attacks. We counted each attacked shoot as well as the total number of current-year and 1-year-old shoots that we believed could have been attacked by *T. piniperda*, i.e., shoots ≥ 3 mm in diameter (Haack et al. unpublished data, Långström 1983, McCullough and Smitley 1995). At the base of each test tree, we measured the depth of the duff layer, brushed the duff layer away to bare soil, marked the tree trunk at the soil line, and then brushed the soil away until the uppermost roots were exposed. We also counted the number of obvious overwintering sites as indicated by piles of frass in bark cracks along the lower trunk of each tree.

We randomly selected 4 of the 12 test trees to be dissected immediately (Trees 1–4; Table 1). We removed all branches in the field and counted all current-year and 1-year-old shoots ≥ 3 mm in diameter, as well as the number of *T. piniperda*-attacked shoots. All attacked shoots were later split open to look for *T. piniperda* adults.

We then cut the trunk of each of the 12 test trees at 3–7 cm below groundline (Table 1). After Trees 1–4 were completely pruned in the field, each stem was bagged separately, taken to the laboratory, and refrigerated until they were dissected during the following week. While debarking the entire main stems of Trees 1–4, we recorded where each *T. piniperda* overwintering site was relative to the original soil line, how many *T. piniperda* adults were inside each overwintering site, and if the adults were alive or dead. All live adults were placed on bark chips and refrigerated. On 16 December 1993, we selected and sexed all uninjured *T. piniperda* adults. To determine if they could reproduce without being exposed to a lengthy cold period, we divided 20 males and 30 females among 3 Scotch pine logs in the laboratory and allowed the beetles to colonize the logs freely. We monitored these cages for brood adult emergence and later debarked the logs and counted and measured all egg galleries.

The remaining 8 trees (Trees 5–12) were taken to the laboratory on 3 December 1993 and placed upright in standard Christmas tree stands. We added water to the stands daily so that the lower 5 cm of each trunk was submerged. All 8 trees were in the same windowless room. Any overwintering *T. piniperda* adults present on these 8 trees were free to fly throughout the lab. Ambient conditions in the lab were 21°–24°C, 20–30% relative humidity, and a 9L:15D photoperiod.

Four of the remaining 8 trees (Trees 5–8) were dissected during 4–10 January 1994. The last 4 trees (Trees 9–12) were taken outdoors again and placed horizontally on the ground in an open area in Ingham County, Michigan, on 5 January 1994. As Trees 5–12 were removed from their individual stands in January, we recorded the number of drowned beetles present inside each stand. After Trees 9–12 had been outdoors for about 7 weeks, we dissected them during 23–24 February 1994. We dissected the last 8 trees as we did the first 4 trees except that we also inspected all trunk sections for *T. piniperda* egg galleries and brood. All adults and brood were classified as alive or dead. We used the Statistical Analysis System (SAS) to analyze the data, using a P=0.05 significance level. The relation between number of attacked shoots per tree and number of overwintering sites per tree was analyzed with simple linear regression.

RESULTS AND DISCUSSION

Tomicus piniperda was able to become active and reproduce in cut Christmas trees that were held indoors during the Christmas season. Dissection of the 50 extra shoots collected on 19 October 1993 indicated that 89% of the shoots contained live *T. piniperda* adults. Therefore, when we tied the 15 shoots on each test tree in October, we were likely adding an average of 13 beetles to each tree. In December, when the 180 tied shoots were collected from Trees 1–12 and dissected, we found 177 empty shoots, 2 shoots with 1 dead *T. piniperda* adult each, and 1 shoot with an aborted attack (Table 1). This pattern of shoot departure closely matched data from another 1993 study at the same Indiana study site, where the presence of *T. piniperda* adults in mostly green shoots was 89% on 19 October, 58% on 4 November, 5% on 16 November, and 0% on 30 November (Haack and Lawrence 1997 and unpublished data).

We found that from 2 to 31 shoots were naturally attacked by *T. piniperda* on Trees 1–12 during 1993 (Table 1). This corresponded to a range in the natural attack rate of the available shoots from 0.2% in Tree 1 and Tree 4 to 4.8% in Tree 6 (Table 1). Considering these naturally attacked shoots and the additional shoots that we tied to each tree, and assuming 1 beetle per attacked shoot, there were potentially 16 to 45 *T. piniperda* per test tree (Table 1). Considering 1 beetle per shoot and 1 beetle per overwintering site, there was no significant linear relation between the number of attacked shoots per tree and number of overwintering sites per tree ($P = 0.11$, N = 12 trees). Tree 12 was the major exception, with 27 potential beetles but only 6 overwintering sites found (Table 1). However, for Trees 1–4, which were dissected while the beetles were still within their overwintering sites and thus the chance of locating all possible overwintering sites and beetles was much higher, there was a significant linear relation between the number of attacked shoots and number of overwintering sites ($r^2 = 0.95$, $P = 0.026$, N = 4 trees). Such data support the contention that *T. piniperda* overwinter on the same trees that they last used for shoot feeding. When Trees 1–4 were dissected, 8% (7 of 90) of the overwintering sites were empty, 89% (80 of 90) contained 1 beetle, and 3% (3 of 90) contained 2 beetles. Several reasons can be given for less than 100% agreement between the number of infested shoots and the number of overwintering sites, such as (a) more than 1 beetle could occur per attacked shoot, (b) more than one shoot per tree could be attacked by the same adult, (c) some shoots could have been attacked in previous years and still have remained attached to the tree, (d) some overwintering sites in the bark could have been created in previous years and some sites could contain more than one beetle, and (e) some beetles could have died, flown to other trees, or fallen off the tree when moving to their overwintering sites.

We located 251 *T. piniperda* overwintering sites on the trunks of Trees 1–12. No beetles were found in shoots of any of the test trees when dissected in December (Trees 1–4), January (Trees 5–8), or February (Trees 9–12). On average, there were 21 overwintering sites per tree found after dissection, but we had seen on average only 7 piles of frass (range 5–9) at the base of each tree in December before cutting. This is explained in part by multiple beetles entering the bark from within the same bark crack. In one case, we found that 5 adults had entered the same bark crack but each had made its own separate tunnel into the bark. The overwintering sites were found from about 1 cm below the original soil line to 40 cm above the soil line (Fig. 2; mean$\pm$SE = 7.3 + 0.3 cm, N=251). Overall, 34% of the overwintering sites were found within the first 5 cm from the soil line, 80% within the first 10 cm, 85% within the first 15 cm, 95% within the first 20 cm, and over 99% within the first 25 cm (Fig. 2). Similarly, with respect to the duff layer, overwintering sites occurred from about 9 cm below the duff line to 35 cm above it (mean$\pm$SE = 2.2 + 0.4 cm, N=251). Overall, 31% of the overwintering sites occurred below the duff line, 72% within the first 5 cm above the duff line,

Table 2. Summary data for the 3 Scotch pine logs that were infested on 16 December 1993 in the laboratory with *Tomicus piniperda* adults that had been removed from their overwintering sites on Scotch pine Christmas trees that had been growing in Indiana.[1]

Log		No. of adult beetles added		Galleries		Gallery	No. of emerged F_1 brood adults			
No.	Area (cm^2)	Males	Females	No. present	No. per m^2	length (cm) (Mean ± SE)	Total	Per gallery	Per cm of gallery	Per m^2 of bark surface area
1	1004[2]	6	10	7	70	7.1 ± 1.1	241	34.4	4.8	2400
2	1048	7	10	10	95	6.7 ± 0.9	303	30.3	4.5	2891
3	1237	7	10	8	65	5.0 ± 0.6	216	27.0	5.4	1746

[1] Adults were removed during 6-10 December 1993 and kept refrigerated until 16 December. Logs were caged individually and maintained at room temperature in the laboratory (see text for details).
[2] Log surface area was calculated using inside-bark diameter measurements.

and 94% within the first 10 cm. These data clearly show that as the cutting height is increased (i.e., the taller the stump), fewer *T. piniperda* adults are potentially transported away with the tree.

Most managers cut Scotch pine Christmas trees from 0 to 10 cm above the ground. They then cut away the lower whorl of branches and then remove another 10 to 15 cm of the basal stem so that the trees are more uniform and can be handled more easily during shipping and by the final buyer (Dr. Melvin R. Koelling, pers. comm.). Therefore, considering that the lower 10–25 cm of trunk are removed and the above data on overwintering site distribution, it is apparent that the vast majority of overwintering beetles remain behind.

The *T. piniperda* adults that we collected in December from Trees 1–4 successfully colonized and reproduced in the laboratory (Table 2). Progeny adults began to emerge on 21 January 1994, with 50% emergence occurring by 28 January, which was about 6 weeks after the parent adults were placed on the logs. Upon dissecting the 3 brood logs, we found 25 egg galleries (Table 2). When presented in terms of F_1 (progeny) adult production/m^2 of log surface area, our results (Table 2) are very similar to the average brood production values for the control logs in other studies that used spring-collected *T. piniperda* adults (1810 to 4351 brood adults/m^2; Långström and Hellqvist 1985, Schroeder and Weslien 1994a, 1994b). Such similarities suggest that the adults in our study reproduced normally after very little exposure to cold.

We first observed *T. piniperda* adults flying in our laboratory on 9 December 1993, which was 6 days after Trees 5–12 were brought indoors. Later, when the Christmas tree stands were inspected in January, we found 30 *T. piniperda* adults in the 8 tree stands (Table 3); all had apparently drowned in the water in the stands. Some of the drowned adults could have been overwintering along that portion of the stem that was submerged, while others could have fallen into the water.

When the entire trunks of Trees 5–12 were dissected after being held indoors for about 4 weeks, we found egg gallery construction in 5 of the 8 trees (Table 3). Overall, we located 26 egg galleries, of which 7 galleries appeared to have been initiated from overwintering sites (Table 3). Of these 26 egg galleries, 17 galleries had no parent adults present when dissected, 7 had 1 adult each, and 2 had 2 adults each. Three of the galleries lacked both parent adults and brood (Table 3). There was much resin in these 3 empty galleries and perhaps they were abandoned for this reason. The fact that parent adults were absent from so many of the egg galleries with brood (61%, 14 of 23 galleries; Table 3) suggests that most adults had had sufficient time to lay eggs and re-emerge before the trees were dissected. Only 1 of the 11 egg galleries with larvae still had a parent adult present upon dissection (Table 3).

The 26 egg galleries found in Trees 5–12 were initiated along the tree trunks from 7 cm to 142 cm above what was the original soil line (Fig. 2). When dissected, larvae were only present in the egg galleries that had been initiated within the first 30 cm of the original soil line (11 of 15 galleries), whereas only eggs were present in galleries constructed above 30 cm (7 of 11 egg galleries). Such variation in brood development suggests that when overwintering on trees that are subsequently cut, *T. piniperda* adults will typically initiate egg gallery construction at or near their overwintering sites. The egg galleries located higher on the stems (above 30 cm) could represent sister broods constructed subsequent to parent adult re-emergence from their initial galleries along the lower stem. These findings, along with the above results on brood production in logs, indicate that *T. piniperda* does not require a lengthy exposure to cold temperatures before reproducing, and thus if

Table 3. Summary *Tomicus piniperda* data for the 8 infested Scotch pine Christmas trees that were harvested in Steuben County, Indiana, on 2 December 1993, kept indoors for about 4 weeks and then either dissected (Trees 5–8) or placed outdoors near East Lansing, Michigan, for 7 weeks and then dissected (Trees 9–12).

Tree No.	No. of dead adults in tree stand in Jan.	No. of adults in		Egg galleries		No. of egg galleries with: [3]							Condition of parent adults or F_1 brood upon dissection
		Shoot	Gallery	No. found	Lth (cm) (Mean ± SE)	No AEL	A	AE	AEL	E	EL	L	
Trees dissected in January 1994 after about 4 weeks indoors													
5	0	0	8	14 (6)[1]	4.8 ± 0.7	1	1	5[2]	1	1	1	4	All alive
6	4	0	0	1	1.4	1	0	0	0	0	0	0	None present
7	0	0	1	2	6.6 ± 1.7	0	0	1	0	1	0	0	All alive
8	4	0	0	0		-	-	-	-	-	-	-	None present
Trees dissected in February 1994 after about 4 weeks indoors and then 7 weeks outdoors													
9	1	0	0	0		-	-	-	-	-	-	-	None present
10	4	0	2	4	3.9 ± 1.6	1	0	1[2]	0	2	0	0	All dead
11	7	0	0	5 (1)	10.0 ± 0.6	0	0	0	0	0	5	0	All dead
12	10	0	0	0		-	-	-	-	-	-	-	None present

[1] Number in ( ) represents the number of galleries on a particular tree that appeared to be initiated from an overwintering site.
[2] For Tree 5, one of the 5 galleries had 2 parent adults present. For Tree 10, 1 gallery had 2 parent adults present.
[3] A=1 or 2 adults present in gallery; E = eggs present; L = larvae present; No AEL = no adults, eggs, or larvae present but appeared to be the start of an egg gallery that was later abandoned due to excessive pitch.

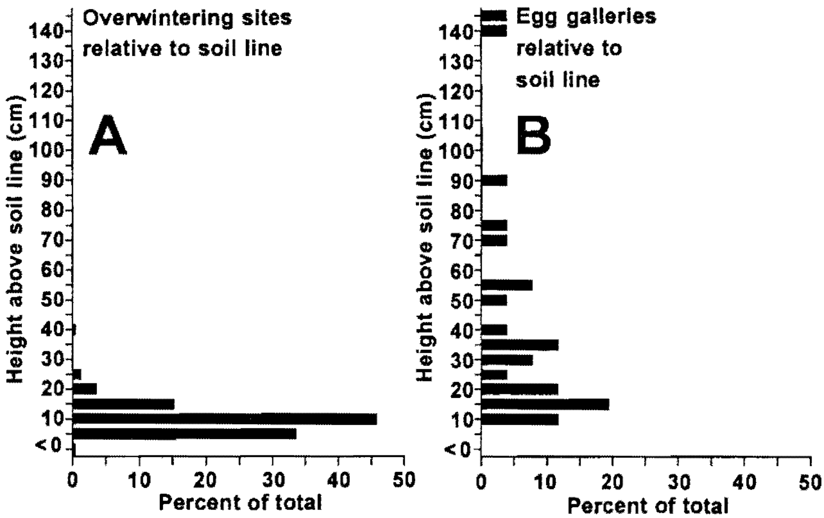

Figure 2. Percent of total *Tomicus piniperda* overwintering sites (A: N=251 on Trees 1–12) or egg galleries (B: N = 26 on Trees 5–12) found at various heights along the trunks of Scotch pine Christmas trees that were harvested in Indiana in December and maintained indoors for 4 weeks (Trees 5-12 only). Heights are given in 5-cm intervals relative to the original soil line at the base of each tree.

moved in cut Christmas trees to a warmer climate, *T. piniperda* could reproduce, if mated, without any further exposure to cold.

All parent adults and progeny in Trees 5–8 were alive when we dissected these trees in early January (Table 3). However, all parent adults and progeny encountered in Trees 9–12, after 7 weeks of exposure to outdoor winter temperatures, were dead (Table 3). Outdoor air temperatures were well below normal during January and February 1994 in East Lansing, Michigan, i.e., average daily temperatures were 3.6°C below normal for January and 1.7°C below normal for February (NOAA 1994). During the 7-week period in January and February when Trees 9–12 were outdoors, East Lansing recorded 14 days where daily minimum temperatures fell below –18°C (= 0°F). Of these 18 days, 6 days fell below –25°C and another 3 days fell between –20° and –25°C (Fig. 3). Given that temperatures below –12.5° and –18.4°C are considered lethal to *T. piniperda* larvae and adults, respectively (Bakke 1968), it is not surprising that all adults and brood in Trees 9–12 were dead. However, during mild winters, it seems possible that some *T. piniperda* parent adults and brood could survive in discarded Christmas trees in the Great Lakes region. If Trees 9–12 had been discarded in the southern United States, where winter temperatures are seldom much below freezing, *T. piniperda* adults and brood would likely have survived the winter period.

Although we recorded *T. piniperda* oviposition in cut Christmas trees, the actual risk of moving *T. piniperda* in cut Christmas trees is likely very low. With the current federal quarantine, only trees from fields that pass a visual inspection or have been managed under the national compliance manage-

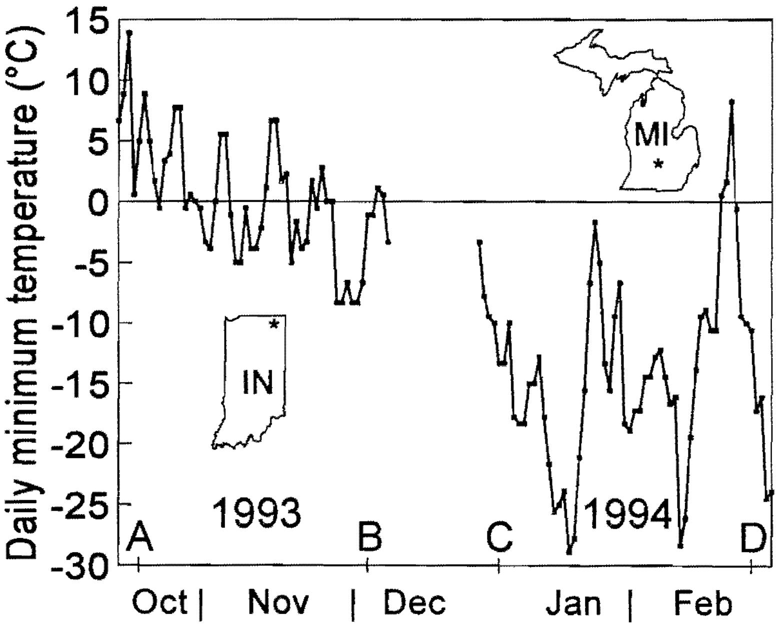

Figure 3. Daily minimum temperatures (°C) from 15 October through 7 December 1993 at Prairie Heights, Steuben County, Indiana (about 10 km from the study site) and from 1 January through 28 February 1994 at East Lansing, Ingham County, Michigan (about 30 km from where Trees 9-12 were stored outdoors for 7 weeks). The asterisk inside each outline map indicates the location of the two study sites and the weather recording stations. Letter A signifies the date when shoots were added to Trees 1-12 (19 Oct 1993); B when trees were cut and returned to Michigan (2 Dec 1993); C when 4 of the trees were placed back outdoors near East Lansing, Michigan (5 Jan 1994); and D when the last 4 trees were returned to the laboratory for dissection (22 Feb 1994).

ment program can be shipped to areas outside the quarantine zone. If an infested pine tree was somehow shipped outside the quarantine zone, there would still be only a remote chance that *T. piniperda* would become established. There are several reasons for this level of relatively low risk. First, well-managed Christmas tree plantations within the infested area generally have very low *T. piniperda* populations, and thus any infested tree would likely contain only one to a few beetles. This is important because few parent females mate before overwintering (10–15%; Janin and Lieutier 1988) and therefore both a male and a female beetle would have to be at the base of the same Christmas tree to ensure reproduction while the tree was indoors. In addition, even if brood production would occur in a Christmas tree outside the quarantine zone, establishment would still be unlikely because the brood adults would disperse upon emergence, shoot-feed all summer on different trees, overwinter, and then have to find each other on the same freshly cut pine log or stump the next spring to mate.

Our results indicate that individuals and municipalities should seriously consider how Christmas trees are disposed after the Christmas season. Depending on local conditions, trees are often placed in landfills, chipped, burned, used to protect garden plantings, or simply thrown outside. To reduce the risk of spreading *T. piniperda*, chipping or burning would certainly be the safest options. In the present study, after Trees 5–12 were indoors for 4 weeks, *T. piniperda* brood ranged from eggs to last-instar larvae. Therefore, Christmas trees should be disposed of quickly after the Christmas season, especially if warm temperatures prevail.

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LITERATURE CITED

Bakke, A. 1968. Ecological studies on bark beetles (Coleoptera: Scolytidae) associated with Scots pine (*Pinus sylvestris* L.) in Norway with particular reference to the influence of temperature. Medd. Norske Skogforsksvesen 21(6), No. 83: 443–602.

Carter, M.C.A., J.L. Robertson, R.A. Haack, R.K. Lawrence, and J.L. Hayes. 1996. Genetic relatedness of North American populations of *Tomicus piniperda* (Coleoptera: Scolytidae). J. Econ. Entomol. 89: 1345–1353.

Haack, R.A. 1997. Early history and spread of *Tomicus piniperda* in North America. Pp. 142–149 *in*: 1997 Japanese beetle and the pine shoot beetle regulatory review: Proceedings, Louisville, Kentucky, 24–26 February 1997. USDA APHIS, Riverdale, Maryland.

Haack B. and D. Kucera. 1993. New introduction—common pine shoot beetle, *Tomicus piniperda* (L.). USDA Forest Service, Northeastern Area, Pest Alert NA-TP-05-93. 2 pp.

Haack, R. A. and R. K. Lawrence. 1995a. Attack densities of *Tomicus piniperda* and *Ips pini* (Coleoptera: Scolytidae) on Scotch pine logs in Michigan in relation to felling date. J. Entomol. Sci. 30: 18–28.

Haack, R. A. and R. K. Lawrence. 1995b. Spring flight of *Tomicus piniperda* in relation to native Michigan pine bark beetles and their associated predators. Pp. 524–535 *in*: F.P. Hain, S.M. Salom, W.F. Ravlin, T.L. Payne, and K.F. Raffa (eds), Behavior, population dynamics and control of forest insects, Proceedings of the joint IUFRO conference for Working Parties S2.07-05 and S2.07-06, Maui, Hawaii, 6–11 February 1994. Ohio State University, Wooster, Ohio.

Haack, R. A. and R. K. Lawrence. 1997. Highlights of Forest Service research on *Tomicus piniperda*: 1992–1996. Pp. 111–118 *in*: 1997 Japanese beetle and the pine shoot beetle regulatory review: Proceedings, Louisville, Kentucky, 24–26 February 1997. USDA APHIS, Riverdale, Maryland.

Haack, R.A., R.K. Lawrence, D.G. McCullough, and C.S. Sadof. 1997. *Tomicus piniperda* in North America: an integrated response to a new exotic scolytid. Pp. 62–72 *in*: J.C. Gregoire, A.M. Liebhold, F.M. Stephen, K.R. Day, and S.M. Salom (eds.), Proceedings: Integrating cultural tactics into the management of bark beetle and reforestation pests. USDA Forest Service, General Technical Report NE-GTR-236.

Janin, J.-L. and F. Lieutier. 1988. Early mating in the life cycle of *Tomicus piniperda* L. (Coleoptera, Scolytidae) in the forest of Orléans (France). Agronomie 8: 169–172. (in French)

Långström, B. 1983. Life cycles and shoot-feeding of the pine shoot beetles. Studia Forestalia Suecica 163: 1–29.

Långström, B. and C. Hellqvist. 1985. *Pinus contorta* as a potential host for *Tomicus piniperda* L. and *T. minor* (Hart.) (Col., Scolytidae) in Sweden. J. Appl. Entomol. 99:174–181.

Långström, B, F. Lieutier, C. Hellqvist, and G. Vouland. 1995. North American pines as hosts for *Tomicus piniperda* (L.) (Col., Scolytidae) in France and Sweden. Pp. 547–557 *in*: F.P. Hain, S.M. Salom, W.F. Ravlin, T.L. Payne, and K.F. Raffa (eds), Behavior, population dynamics and control of forest insects, Proceedings of the joint IUFRO conference for Working Parties S2.07-05 and S2.07-06, Maui, Hawaii, 6–11 February 1994. Ohio State University, Wooster, Ohio.

Lawrence, R. K. and R. A. Haack. 1995. Susceptibility of selected species of North American pines to shoot-feeding by an Old World scolytid: *Tomicus piniperda*. Pp. 536–546 *in:* F.P. Hain, S.M. Salom, W.F. Ravlin, T.L. Payne, and K.F. Raffa (eds), Behavior, population dynamics and control of forest insects, Proceedings of the joint IUFRO conference for Working Parties S2.07-05 and S2.07-06, Maui, Hawaii, 6–11 February 1994. Ohio State University, Wooster, Ohio.

McCullough, D.G. and C.S. Sadof. 1996. Pine shoot beetle compliance program for Christmas trees: A manual for Christmas tree growers. Michigan State University Extension, Extension Bulletin E-2615. 15 pp.

McCullough, D.G. and D.R. Smitley. 1995. Evaluation of insecticides to reduce maturation feeding by *Tomicus piniperda* (Coleoptera: Scolytidae) in Scotch pine. Journal of Economic Entomology 88: 693–699.

NOAA (National Oceanic and Atmospheric Administration). 1994. Climatological data, annual summary, Michigan, 1994. National Climatic Data Center, Asheville, North Carolina. 35 pp.

Sadof, C.S., R.D. Waltz, and C.D. Kellam. 1994. Differential shoot feeding by adult *Tomicus piniperda* (Coleoptera: Scolytidae) in mixed stands of native and introduced pines in Indiana. Great Lakes Entomol. 27: 223–228.

Schroeder, L.M. and J. Weslien. 1994a. Interactions between the phloem-feeding species *Tomicus piniperda* (Col.: Scolytidae) and *Acanthocinus aedilis* (Col.: Cerambycidae), and the predator *Thanasimus formicarius* (Col.: Cleridae) with special reference to brood production. Entomophaga 39: 149–157.

Schroeder, L.M. and J. Weslien. 1994b. Reduced offspring production in bark beetle *Tomicus piniperda* in pine bolts baited with ethanol and α-pinene, which attract antagonistic insects. Journal of Chemical Ecology 20: 1429–1444.

USDA APHIS (US Department of Agriculture, Animal and Plant Health Inspection Service). 1992. 7 CFR Part 301—Pine shoot beetle. Federal Register, 19 November 1992. 57(224): 54492–54499.

USDA APHIS. 1996. Pine shoot beetle compliance management program. USDA APHIS, Plant Protection and Quarantine, Domestic and Emergency Programs, Riverdale, Maryland. 24 pp.