

**Attack Densities of *Tomicus piniperda* and *Ips pini*  
(Coleoptera: Scolytidae) on Scotch Pine Logs  
in Michigan in Relation to Felling Date<sup>1</sup>**

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**ABSTRACT** Established populations of an exotic bark beetle, the larger pine shoot beetle [*Tomicus piniperda* (L.)], were first reported in Ohio in July 1992. Subsequent surveys through July 1994 have found *T. piniperda* in six states in the United States and in one Canadian Province in the Great Lakes region. One-meter-long trunk sections were cut from Scotch pine (*Pinus sylvestris* L.) trees felled from February through July 1993 in a forested site in southern Michigan, laid horizontally, allowed to undergo natural attack by bark beetles and associates, and later dissected. In southern Michigan in 1993, *T. piniperda* initiated spring flight in late March; the pine engraver [*Ips pini* (Say)], a native pine bark beetle, initiated spring flight about one month later in late April. *Tomicus piniperda* attacks (galleries) were found in logs cut during February through May. Attack densities of *T. piniperda* were highest in February-cut logs, and declined with subsequent felling dates. The highest *T. piniperda* attack density recorded for an entire log section was 263 attacks/m<sup>2</sup> of bark area on one of the February-cut logs. *Ips pini* attack densities tended to increase with later felling dates. When *I. pini* attacked logs that had already been colonized by *T. piniperda*, *I. pini* galleries were mostly found on the upper log surface. When *I. pini* attacked logs with few or no *T. piniperda*, *I. pini* galleries were found on all log surfaces. By initiating spring flight several weeks before *I. pini*, *T. piniperda* is able to colonize much of the susceptible pine material and thereby may lower *I. pini* populations.

**KEY WORDS** *Ips pini*, *Tomicus piniperda*, Coleoptera, Scolytidae, bark beetle, Scotch pine, *Pinus sylvestris*, attack density, Michigan, North America

The native range of the larger pine shoot beetle, *Tomicus piniperda* (L.) (Coleoptera: Scolytidae), covers much of Europe, Asia, and North Africa, where this beetle infests several species of pine (*Pinus*). In July 1992, established populations of *T. piniperda* were discovered near Cleveland, OH (Haack and Kucera 1993), and by late July 1994, this bark beetle had been found in 112 counties in the 6 states of Illinois, Indiana, Michigan, Ohio, New York, and Pennsylvania, and in 8 counties in Ontario, Canada (Fig. 1). A federal quarantine is now in effect that controls movement of pine material from regulated (infested) counties to unregulated (uninfested) counties (APHIS 1993).

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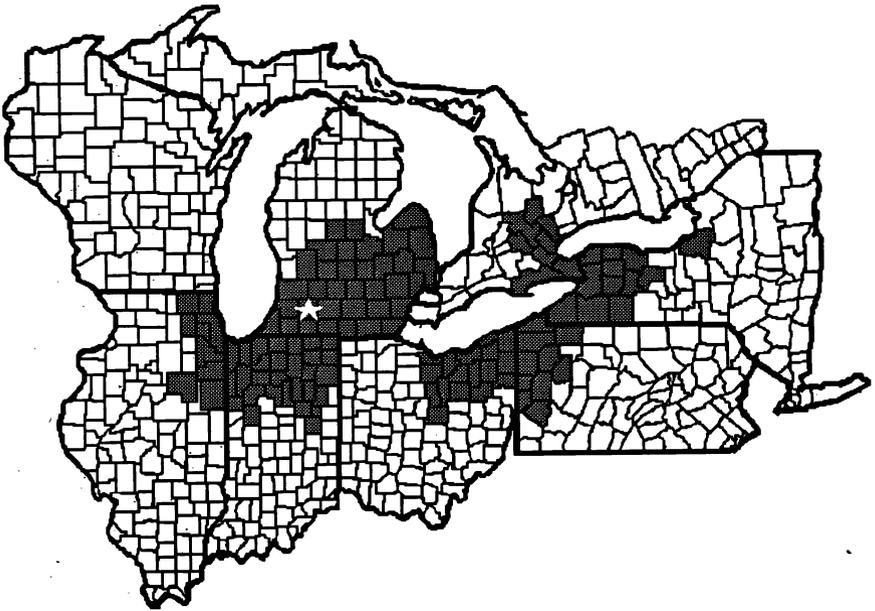


Fig. 1. Counties in the United States (112 counties) and Canada (8) with established populations of *Tomicus piniperda* as of July 1994 (Source: USDA APHIS, Hyattsville, Maryland; and Agriculture Canada, Ottawa, Ontario). The present study occurred in Kalamazoo County, Michigan, which is designated by a star.

The current distribution of *T. piniperda* suggests that this beetle probably entered North America sometime in the 1980s and simply went undetected until 1992. This beetle probably arrived on cargo ships, at one or more Great Lakes ports, in infested crating material or dunnage (logs used to support cargo). It is likely that the beetles in North America are of European origin because more than 95% of recent interceptions of *T. piniperda* in the United States have been from Europe (USDA, APHIS, unpublished data; see Haack and Lawrence 1995). *Tomicus piniperda* is one of more than 360 exotic insects of woody plants that are now established in North America (Haack and Byler 1993, Mattson et al. 1994).

A brief description of *T. piniperda*'s univoltine life cycle follows, based primarily on Bakke (1968), Långström (1983) and Haack and Lawrence (1995). Adults overwinter in the outer bark at the base of pine trees, usually on the

same trees on which they were last shoot-feeding. In early spring, adults become active and fly to recently cut pine stumps and logs for breeding. Adult females initiate attack and soon each is joined by a single male. Neither sex of *T. piniperda* is known to produce aggregation pheromones. The female constructs a longitudinal egg gallery, laying eggs in individual egg niches on both sides of the egg gallery. Parent adults can re-emerge and initiate new attacks. Larvae typically complete development in about 6 to 10 wk with the new brood adults beginning to emerge in late spring. After they emerge, brood adults fly to the crowns of living pine trees and enter shoots often near the distal tip of current-year shoots. They feed inside one or more shoots during summer and autumn, and thereby cause shoot death. In autumn, adults exit the shoots over about a 1-month period starting within days after the first few nights of sub-freezing temperatures. After exiting, adults typically walk along the branch to the tree trunk and then down to groundline, where they overwinter in short individual tunnels they make in the outer bark.

*Tomicus piniperda* is the first pine bark beetle to fly in spring in Europe, often flying several weeks before the others (Bakke 1968, Eidmann 1974, Långström 1983, Bouhot et al. 1988). This behavior reflects *T. piniperda*'s relatively low temperature threshold for flight, i. e., 10-12°C, compared with 14-20°C for the other major pine-infesting scolytids in Europe (Bakke 1968, Annala 1969). The ability to fly at such low temperatures allows *T. piniperda* to colonize susceptible pine material (e.g., recently cut pine stumps and logs) for several weeks without interspecific competition.

In the Great Lakes region of North America, the pine engraver, *Ips pini* (Say) (Coleoptera: Scolytidae), is the most economically important pine bark beetle (Schenk and Benjamin 1969, Raffa 1991). Other pine bark beetles that co-occur with *I. pini* include: *Dendroctonus valens* LeConte, *Ips grandicollis* (Eichhoff), and *Orthotomicus caelatus* (Eichhoff). These four scolytids and their major coleopterous predators in the families Cleridae, Histeridae, and Tenebrionidae typically initiate spring flight in late April or May (Thomas 1961, Schenk and Benjamin 1969, Raffa 1991, Haack and Lawrence 1995). In Michigan in 1993, *T. piniperda* flew 4-5 weeks before the native pine bark beetles and associates, i.e., late March vs. late April (Haack and Lawrence 1995).

Our main objective in the present study was to determine the length of time that *T. piniperda* would continue to infest newly cut pine logs when felled at various times from February through July in southwestern Michigan. This information would help evaluate current quarantine regulations that are imposed on the shipment of pine logs to destinations outside of the quarantine zone. A secondary objective was to assess the degree of interspecific competition between *T. piniperda* and *I. pini* in pine logs cut at various times throughout the flight season of these beetles.

## Materials and Methods

This study was conducted at the W. K. Kellogg Experimental Forest of Michigan State University near Augusta, Kalamazoo County, Michigan, in 1993 (Fig. 1). A related project to compare seasonal flight of *T. piniperda* to that

of native pine bark beetles and their coleopterous predators also was conducted at this site in 1993 (Haack and Lawrence 1994).

To monitor changes in the colonization pattern of pine logs, one or more Scotch pine trees, 15-30 cm diam at breast height (1.4 m above groundline), were felled on 13 dates in 1993: one felling date in February, four in April, four in May, two in June, and two in July. Two 1-m-long, rough-barked sample logs were cut from the lower trunk of each tree. Logs were placed horizontally near the edge of pine stands where they received shade for much of the day. Each log was supported 5 to 10 cm off the ground by two Scotch pine branch sections to allow easy colonization of the entire log surface. After placement, the top surface of each log was indicated by marking the log's cut ends with a carpenter's pencil; these marks were used as a reference point during later dissection. Logs were allowed to be infested freely by all scolytids and associates.

Logs cut between February and May were debarked with drawknives and wood chisels in late June 1993, and logs cut in June and July were debarked in early October 1993. The surface area of each log was calculated as a cylinder, using length and diameter-inside-bark measurements. The diameter value used for each log was an average of four measurements, two taken at right angles on each cut end. After debarking, we counted all *T. piniperda* and *I. pini* attacks, i.e., egg galleries. For *I. pini*, although they are polygamous bark beetles, each gallery system was counted as a single attack regardless of the number of egg galleries radiating from the nuptial chamber. For each log, we determined attack densities for both *T. piniperda* and *I. pini*, the percentage of scolytid attacks that each bark beetle species represented, and the location of their attacks on the log surface. In addition, we noted the extent of colonization by cerambycid and curculionid larvae.

We used the Statistical Analysis System (SAS Institute 1988) to analyze the data for significant differences at the level  $P \leq 0.05$ . Percentage data were transformed before analysis, using arcsin-square root. Means were separated using one-way ANOVA and the Student-Newman-Keuls multiple range test.

## Results

A total of 27 Scotch pine logs, cut between February and July, was sampled (Table 1). Logs from trees cut during February through May were infested almost exclusively by *T. piniperda* and *I. pini*. However, logs from trees cut in June and July were attacked primarily by cerambycids (*Monochamus* sp.) and curculionids (*Pissodes approximatus* Hopkins). Because no *T. piniperda* galleries were found in the June- or July-cut logs, these samples were not included in the analyses below.

Overall, mean attack density of *T. piniperda* significantly declined ( $P < 0.0001$ ;  $df = 4,18$ ;  $F = 19.4$ ) with succeeding felling dates, and that of *I. pini* generally increased ( $P < 0.04$ ;  $df = 4,18$ ;  $F = 3.2$ ; Fig. 2). Mean attack density of *T. piniperda* ranged from 179 attacks/m<sup>2</sup> of bark area (range = 108-263) for logs cut in February to 2 attacks/m<sup>2</sup> (range = 0-8) for logs cut in late May. In contrast, average attack density of *I. pini* ranged from 4 attacks/m<sup>2</sup> (range = 0-18) for logs cut in February to 26 attacks/m<sup>2</sup> (range = 3-46) for logs cut in early May.

**Table 1.** Summary data for Scotch pine logs cut from February through May 1993 at the Kellogg Forest in Michigan, and dissected in June 1993.

Parameter	Cutting date				
	February	Early April	Late April	Early May	Late May
No. of logs	6	5	3	4	5
Mean log diam (cm)	20.1	17.0	19.5	13.4	18.1
Log diam range (cm)	18-22	14-22	18-21	10-20	11-29
Total log surface area (m <sup>2</sup> )	3.2	2.7	1.7	1.6	2.5
Total <i>T. piniperda</i> attacks	571	221	84	53	3
Total <i>I. pini</i> attacks	13	16	16	42	19

Similarly, the mean percentage of all scolytid attacks that were made by *T. piniperda* for a given felling date significantly declined ( $P < 0.0001$ ;  $df = 4, 18$ ;  $F = 34.7$ ) with succeeding felling dates, and that of *I. pini* increased ( $P < 0.0001$ ;  $df = 4, 18$ ;  $F = 34.7$ ; Fig. 3). Mean percentage of all attacks made by *T. piniperda* on a given date ranged from 97% (range = 86-100%) for logs cut in February to 10% (range = 0-50%) for logs cut in late May. Similarly, mean percentage of all scolytid attacks made by *I. pini* on a given date ranged from 3% (range = 0-14%) for logs cut in February to 90% (range = 50-100%) for logs cut in late May. Attacks by *T. piniperda* were found on all logs cut during February through May except for four of five logs cut in late May. Attacks by *I. pini* were found on all logs except for four of the six February-cut logs and two of five logs cut in early April.

In February-cut logs, *T. piniperda* attacks covered nearly the entire log surface; the few *I. pini* attacks found on these logs were near the cut ends on the upper log surface. In April-cut logs, *T. piniperda* attacks covered most log surfaces, but the fewest attacks were on the upper surface. In contrast, it was along the upper surface of the April-cut logs where most *I. pini* galleries were found. In the May-cut logs, only a few *T. piniperda* attacks were found and they were mostly on the sides of the logs, whereas *I. pini* attacks were found on nearly all log surfaces.

## Discussion

### Attack Density, Seasonal Flight and Management Implications.

Seasonal changes in attack densities of *T. piniperda* and *I. pini* reflect primarily the differences in timing of each scolytid's initial spring flight. At Kellogg Forest where the present study occurred, *T. piniperda* initiated spring flight on 29 March 1993, while *I. pini* initiated flight on 26 April (Haack and Lawrence 1995). Therefore, the February felling date in the present study preceded initial flight of *T. piniperda* and *I. pini* by about 4 and 8 wk,

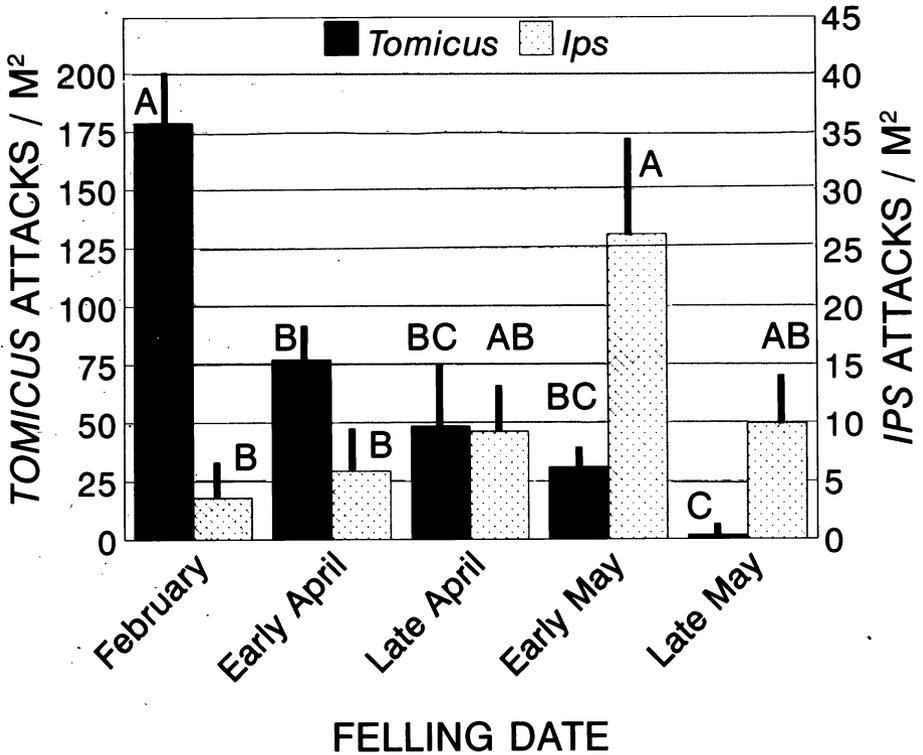


Fig. 2. Mean attack densities of *T. piniperda* and *I. pini* on Scotch pine logs by felling date (note differences in scale for the two scolytids); trees were felled on various times from February to May 1993 and sample logs were allowed to undergo natural attack from the time of felling to late June 1993 at the Kellogg Forest, Augusta, Michigan. For each scolytid separately, means with the same letter are not significantly different at the  $P = 0.05$  level, SNK test; the vertical line on each bar represents 1 SEM.

respectively. The April felling dates occurred 1 to 4 wk after *T. piniperda* initial flight, but preceded *I. pini* initial flight by about 1 day to 3 wk. The May through July felling dates occurred after initial flight by both scolytids.

Spring flight of *T. piniperda* typically occurs as a burst of flight activity in just a few days followed by a long tail of minor flight activity over the next 1 to 3 months (Bakke 1968, Långström 1983, Saarenmaa 1983, Haack and Lawrence 1995). Such a flight pattern is reflected in the high *T. piniperda* attack densities on those logs cut prior to initial flight compared with logs cut after initial flight had commenced (Fig. 2). Similar changes in *T. piniperda* attack density over time were recorded by Löyttyniemi and Uusvaara (1977), and Långström (1986) in Europe.

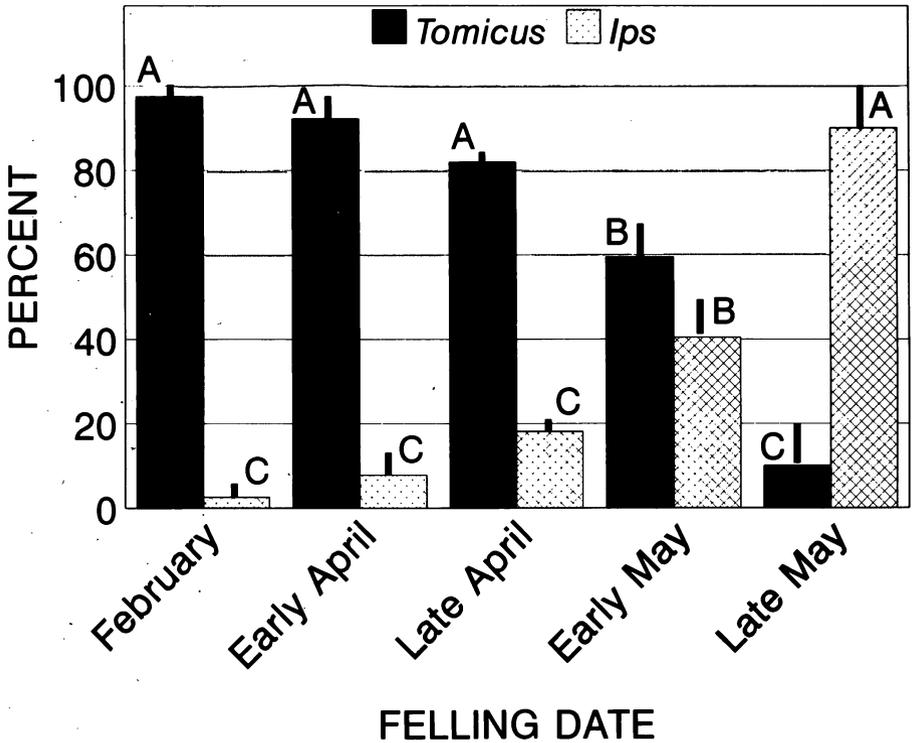


Fig. 3. Mean percent of all scolytid attacks that were created by either *T. piniperda* or *I. pini* on Scotch pine logs by felling date; trees were felled on various dates from February to May 1993 and allowed to undergo natural attack from the time of felling to late June 1993 at the Kellogg Forest, Augusta, Michigan. For each scolytid separately, means with the same letter are not significantly different at the  $P = 0.05$  level, SNK test; the vertical line on each bar represents 1 SEM.

The *T. piniperda* attack densities of 108 to 263 attacks/m<sup>2</sup> that we noted for the February-cut logs are similar to values reported for *T. piniperda* in many European studies. However, the highest attack density value of 263 attacks/m<sup>2</sup> at Kellogg Forest was less than the highest values recorded in some European studies: 335 *T. piniperda* attacks/m<sup>2</sup> as reported by Nilssen (1978), 432 by Saarenmaa (1983), and 404 by Långström (1984).

The long tail of *T. piniperda* flight activity likely represents parent adults that have reproduced one or more times and have re-emerged again to search for additional oviposition sites (Långström 1983). In laboratory studies, Sauvard (1993) demonstrated that *T. piniperda* parent females construct an average of two egg galleries each. The *T. piniperda* adults that attacked April- and May-cut

logs in the present study were most likely starting their second or third egg galleries. The lowering of *T. piniperda* attack densities on April- and May-cut logs probably reflects increased mortality of *T. piniperda* parent adults through time.

Although *T. piniperda* parent adults were caught in flight traps through 10 June 1993 at Kellogg Forest (Haack and Lawrence 1995), no *T. piniperda* egg galleries were found in the June- or July-cut logs. The lack of *T. piniperda* galleries in the June- and July-cut logs may foretell what will typically occur in Michigan, or it may be an artifact of the relatively small sample size we used and a single year's data. Additional studies on this topic are needed to provide a basis for refining current federal quarantine regulations that allow logs from newly cut pine to be transported from regulated (infested) to unregulated (uninfested) counties without debarking or fumigation from 1 July to 31 October (APHIS 1993). The rationale for a starting date of 1 July is that *T. piniperda* is not expected to initiate egg galleries on pine trees felled after that date. Based on results of the present study the 1 July starting date appears to pose little risk of moving *T. piniperda*. However, this date may not be sufficiently safe if *T. piniperda* moves further north into cooler areas. For example, in Scotland and Scandinavia, *T. piniperda* parent adults have been observed to attack logs cut as late as June (Eidmann 1974, Långström 1983), July (Savory et al. 1970, Långström 1986), or even August (Hanson 1940).

Our results have important implications for the use of trap logs in monitoring or managing *T. piniperda*. In the case of monitoring, it is best to deploy logs before adult flight begins, but deployment during the first month after initial flight should still prove useful for detection surveys. As a management technique to reduce local populations, logs should always be deployed prior to adult flight to attract the largest numbers of parent adults. Log deployment after two or more months since initiation of flight will attract relatively few *T. piniperda* parent adults. Similarly, these results can be used to predict how timing of logging operations will affect build-up of *T. piniperda* populations. For example, in the Great Lakes region, logging between June and September will have little effect on *T. piniperda* populations, but it will favor *I. pini* populations because this multivoltine bark beetle is reproductively active throughout the summer months (Schenk and Benjamin 1969).

**Within-Log Colonization Patterns and Interspecific Competition.** For logs that receive direct sunlight for much of the day, few if any subcortical insects can successfully colonize the upper portions exposed to sunlight because temperatures are so extreme (Bakke 1968, Haack and Slansky 1987). Therefore, logs in the present study were positioned to receive little direct sunlight so as to minimize temperature effects on subsequent colonization. Overall, *T. piniperda*'s near complete colonization of logs deployed in February probably reflects the relatively high numbers of *T. piniperda* adults seeking oviposition sites early in the flight season. By contrast, the lack of *T. piniperda* galleries along the upper surface of April- and May-cut logs likely reflects the lower number of *T. piniperda* available to attack as well as their preference to colonize first the sides of logs. Similarly, in Europe, *T. piniperda* tends to colonize all log surfaces early in the flight season (Dowding 1973, Eidmann 1974), but later in the flight season, as temperatures warm, *T. piniperda* tends to attack mostly the sides of logs while other bark beetles and weevils attack

the upper log surface (Krol 1980, Bouhot et al. 1988). Bakke (1968) has shown that *T. piniperda* prefers cooler temperatures than the other pine-infesting bark beetles of Europe.

In the February-cut logs, *I. pini* galleries were found only at the cut ends of a few logs. These sites were probably the only locations still available for colonization when *I. pini* flew in late April. Similarly, on the April-cut logs, *I. pini* was again restricted to areas of the logs (i.e., the upper surface) that had not already been attacked by *T. piniperda*. The occurrence of *I. pini* galleries on all surfaces of May-cut logs probably reflects that *I. pini* was active and at higher densities at the time of tree felling, and that it encountered little interspecific competition from *T. piniperda*.

If suitable host material is limited, *T. piniperda* may lower *I. pini* populations by colonizing much of the early season, susceptible pine material - host material that before *T. piniperda*'s arrival was almost entirely colonized by *I. pini*. This discussion of competition implies that these two bark beetles compete for the same portion of a tree. On Scotch pine in Europe, *T. piniperda* tends to attack mostly the lower trunk where the bark is relatively rough, while the other pine bark beetles concentrate in the upper trunk and branches where the bark is smooth (Salonen 1966, Bakke 1968, Annila and Petäistö 1978, Führer and Kereck 1978, Bouhot et al. 1988, Schlyter and Löfqvist 1990). However, many North American pines have rough outer bark along their trunks and major branches and on such pines, *T. piniperda*'s within-tree distribution will likely be much broader than that found on Scotch pine. We do know that *T. piniperda* can successfully reproduce and shoot-feed in all native pines in the Great Lakes region: jack pine (*Pinus banksiana* Lamb.), red pine (*P. resinosa* Ait.), and eastern white pine (*P. strobus* L.) (Lawrence and Haack 1995). Future studies should address this question of competition by comparing the within-tree colonization patterns in areas where both scolytids occur as well as in areas where only *I. pini* is found.

*Tomicus piniperda* is one of the most recent exotic forest insects to arrive in North America (Haack and Byler 1993, Mattson et al. 1994), but given its current wide distribution (Fig. 1), eradication is not feasible. Moreover, being the first pine bark beetle to fly in spring gives *T. piniperda* a competitive advantage over the native pine bark beetles. For this reason and several others (Haack and Lawrence 1995, Lawrence and Haack 1995), *T. piniperda* will likely be very successful in North America. Managers of forests, Christmas tree plantations, and nurseries will need to alter many of their current practices to abide by current quarantine regulations as well as to minimize future impacts by this exotic bark beetle.

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