# Growth reduction of Scots pine, *Pinus sylvestris,* caused by the larger pine shoot beetle, *Tomicus piniperda* (Coleoptera, Scolytidae), in New York State

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**Abstract**: Dendrochronological techniques were used to (1) estimate the impact of shoot feeding by the exotic bark beetle *Tomicus piniperda* (L.) (Coleoptera, Scolytidae) in an unmanaged 35-year old Scots pine, *Pinus sylvestris* L., stand in New York State and (2) back-date the probable time of arrival of this beetle to the study site. Increment cores were taken from overstory trees with severe and moderate crown damage, as no undamaged or lightly damaged trees were present in the study site. In 1989, average growth patterns of both damage classes began to diverge, and in 1995 the average annual basal area increment of trees with severely damaged crowns was 50% less than that of trees with moderately damaged crowns. Over the last 7 years (1989–1995) the mean periodic basal area increment of trees with severely damaged crowns was 37% less than that of trees with moderately damaged crowns. This is the first report of growth loss of Scots pine caused by *T. piniperda* in North America. Tree-ring data suggest that *T. piniperda* arrived in the stand possibly prior to 1982 and unquestionably before 1989. This was further supported by the growth patterns of hardwood species sampled throughout the study site. This is the first attempt to estimate the time of arrival of this beetle to North America. The damage to Scots pine estimated in this study, together with preferences for certain North American pine species, indicates a potential for serious damage as *T. piniperda* spreads to major pine-growing regions throughout North America.

**Résumé** : La dendrochronologie a été utilisée pour (1) évaluer l'impact de l'attaque des pousses par le scolyte exotique *Tomicus piniperda* (L.) (Coleoptera, Scolytidae) dans un peuplement de 35 ans non aménagé de pin sylvestre, *Pinus sylvestris* L., situé dans l'État de New York et (2) retracer à quel moment cet insecte serait arrivé dans le site sous étude. Des carottes furent prélevées sur des arbres de l'étage dominant dont la cime montrait des dommages sévères et modérés étant donné qu'il n'y avait pas d'arbres exempts de dommages ou avec des dommages légers dans le site étudié. En 1989, les patrons de croissance moyenne des arbres dans les deux classes de dommage ont commencé à diverger et en 1995 l'accroissement annuel moyen en surface terrière des arbres dont la cime était sévèrement endommagée était inférieur de 50% à celui des arbres dont la cime était modérément endommagée. Au cours des sept dernières années (1989-1995), l'accroissement périodique moyen en surface terrière des abres dont la cime était sévèrement endommagée était inférieur de 37% à celui des arbres dont la cime était modérément endommagée. C'est la première mention d'une réduction de croissance chez le pin sylvestre causée par *T. piniperda* en Amérique du Nord. Les données dendrochronologiques suggèrent que *T. piniperda* est probablement arrivé dans ce peuplement avant 1982 et sans aucun doute avant 1989. Ce fait est également supporté par les patrons de croissance des espéces feuillues échantillonnées un peu partout dans le site. Il s'agit du premier essai pour estimer à quel moment cet insecte est arrivé en Amérique du Nord. Les dommages au pin sylvestre relevés dans cette étude et les préférences de cet insecte pour certaines espèces de pin de l'Amérique du Nord montrent que *T. piniperda* pourrait causer des dommages importants à mesure qu'il s'étend aux principales régions où croissent les pins à travers l'Amérique du Nord.
[Traduit par la Rédaction]

## Introduction

The pine shoot beetle, *Tomicus piniperda* (L.) (Coleoptera, Scolytidae), is an exotic pest recently introduced to North America. It was first detected in the United States in July 1992 near Cleveland, Ohio (Haack et al. 1997). By October 1996, surveys showed that Michigan, Illinois, Indiana, Ohio, Pennsylvania, New York, West Virginia, Maryland, and southern Ontario were already infested (Haack et al. 1997). Carter et al. (1996) suggested that at least two introductions of *T. piniperda* have occurred: one in Illinois near lake Michigan and one in Ohio along Lake Erie.

In its native range of Europe and Asia, *T. piniperda* is one of the most destructive insect pests affecting pines (Ratzeburg 1839; Ritchie 1917; Escherich 1923; Hanson 1937; Nunberg 1946; Salonen 1973; Långström 1980). In China, this beetle has damaged eight pine species and caused serious economic losses to over 8.3 million ha of Yunnan pine, *Pinus yunnanensis* L., in Kunming Province (Ye 1994). The pine shoot beetle can cause 20–45% volume growth loss in Europe over periods of up to 10 years (Långström 1980, and references therein; Långström and Hellqvist 1991). In Poland, losses of 34% in annual volume increment and 39% in volume over a 6-year period were reported (USDA 1972). In Europe, *T. piniperda* attacks Scots pine, *Pinus sylvestris* L., but in the United States

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and Europe, it will shoot feed and breed in at least 12 species of North American hard and soft pines (Sierpiński 1969; Långström and Hellqvist 1985; Zumr 1992; Sadof et al. 1994; Långström et al. 1995; Lawrence and Haack 1995).

*Tomicus piniperda* breeds in the inner bark of freshly cut or fallen timber, or very weakened trees. Soon after development is completed, new adults fly to the tops of tree crowns of both weakened and healthy trees where they feed by mining lateral shoots until reaching sexual maturity. During maturation feeding, tunneled shoots usually break and fall to the ground. Each beetle can damage up to six shoots (Långström 1980). Trees are damaged through the loss of 1 or 2 years of photosynthetic tissue, which results in a reduction in yearly growth increment. In extreme cases, trees weakened by shoot feeding may become available as breeding material.

Growth loss estimates associated with insect pests are well documented (Duff and Nolan 1953; Mott et al. 1957; USDA Forest Service 1985; Hornbeck et al. 1988; Fritts and Swetnam 1989). The majority of such studies are devoted to periodic outbreaks of defoliating insects that damage the current or previous year's foliage. Defoliated trees have the ability to refoliate within the same or next growing season. These outbreak populations of defoliating insects typically cause short-term, dramatic decreases in radial growth, which are readily distinguishable using standard dendrochronological techniques. Unlike foliovores, lateral shoot feeding by *T. piniperda* causes permanent damage because the shoots cannot be easily replaced by the tree. Therefore, annual reductions in radial increment may not be dramatic, but the cumulative effect of repeated attacks can be significant. *Tomicus piniperda* does not generally occur in outbreak populations. However, local populations can build over time in areas where breeding material is abundant.

The only effective method for controlling *T. piniperda* populations in Europe has been intensive silvicultural sanitation (Hanson 1937; Nunberg 1946; Davies and King 1977; Hibberd 1991). In addition, predators and parasitoids help reduce Eurasian *T. piniperda* populations (Hanson 1937).

In this study, increment cores from severely and moderately damaged Scots pines were taken to estimate growth loss caused by *T. piniperda* and to estimate the approximate arrival date of this insect to the stand. This is the first report of growth loss caused by *T. piniperda* in North America.

## Materials and methods

The study site was located 5 km west of Lockport, New York, Niagara County, one of the original areas found to be infested by *T. piniperda* in 1992 (see fig. 1 in Carter et al. 1996). Research was conducted in an unmanaged 35-year-old Scots pine plantation. This isolated, 3-ha stand grows on poorly drained soils and was planted to increase property value. There are numerous Scots pine stands in the area, some of which are lightly damaged by *T. piniperda*. These could not be used as control stands because they are of different ages, management histories, and (or) site conditions.

In a preliminary study in 1995, 11 circular 0.04-ha fixed-area plots were established throughout the stand in a uniformly spaced 50 × 50 m design. Within each plot, the diameter at breast height (DBH = 1.3 m) of all trees greater than 6 cm was measured and the crown position noted. Scots pine dominates the stand with 1042 ± 79 trees/ha and an average annual basal area of 21.61 ± 2.15 $m^2$/ha. Several competing hardwood species were also present including black ash, *Fraxinus nigra* Marsh. (383 ± 103 trees/ha and 3.46 ± 0.82 $m^2$/ha), American elm, *Ulmus americana* L. (126 ± 66 trees/ha and 1.99 ± 0.93 $m^2$/ha), and silver maple, *Acer saccharinum* L. (40 ± 15 trees/ha and 0.74 ± 0.33 $m^2$/ha). All Scots pines in the stand had some level of crown damage by *T. piniperda*. Crown damage was assessed visually and trees were assigned to damage categories by the percentage of missing lateral shoots in the crowns. Lightly, moderately, and severely damaged trees had crowns missing 5–25, 26–50, and more than 50% of lateral shoots, respectively.

To eliminate the possible effects of competition from hardwood species growing naturally in the study site, growth analysis was restricted to individual trees in areas of nearly pure Scots pine. Analysis of the 0.04-ha plots showed that there was a significant positive association ($R^2 = 0.64$, $P = 0.003$, $n = 11$) between the frequency of severely damaged dominant and codominant Scots pine and the percentage of basal area occupied by dominant and codominant hardwood species. This suggested that crown condition may be affected by the interaction of both beetle damage and hardwood competition.

To determine the influence of climatic events on tree growth, increment cores were taken from 17 hardwood trees (black ash, $n = 12$; silver maple, $n = 5$) throughout the experimental stand as well as from three Scots pines and three red pines, *Pinus resinosa* Ait., from a nearby stand.

By 1996, there were no trees with lightly damaged crowns present in the study site; therefore the only possible growth comparison was between severely and moderately damaged Scots pines. Only overstory trees were analyzed. Nine severely damaged trees and eight moderately damaged trees were selected for comparison. Two increment cores per tree were taken at breast height at 120° from each other. Cores were glued to plywood mounting boards and polished with 400-grit sand paper. Annual growth increments were measured using a dissecting microscope and the Unislide Tree Ring Measuring System equipped with the Acu-Rite sliding scale and linear encoder. This was interfaced with the Quick-Check QC-1000 digital measuring device (Velmex, Inc., East Bloomfield, N.Y.) and recorded on a computer.

All tree ring series were graphically cross-dated. The average annual radial increments for each tree were calculated and then converted to basal area increments. The two 35-year series were truncated to 21-year series (1975–1995) to eliminate variability in growth prior to crown closure (Fritts and Swetnam 1989). The two 21-year series were then divided into three 7-year periods because the two damage class dendrochronologies began to diverge in 1989 (Fig. 1). Statistical analysis was conducted for the 21-year period as well as for the three 7-year periods to isolate the recent effects of shoot feeding. Within each period, linear regression was performed on each damage class and the regression lines of the average annual basal area increments over time were compared for differences in slope and coincidence using SAS, PROC REG (SAS Institute, Inc. 1985).

In a separate analysis, three 7-year periodic basal area increments were calculated for each tree. Statistical analysis was performed on log-transformed data to satisfy ANOVA assumptions. Within each period, a *t*-test was used to test for differences in mean periodic basal area increment between the damage classes (StatSoft, Inc. 1995).

## Results and discussion

In 1996, there were no trees with lightly damaged crowns present in the stand. In 1989, growth patterns of severely and moderately damaged trees began to diverge, and in 1995 the average annual basal area increment of trees with severely damaged crowns was 50% less than that of trees with moderately damaged crowns (Fig. 1). Over the last 7 years (1989–1995) the mean periodic basal area increment of trees with severely damaged crowns was 37% less than that of trees with moderately damaged crowns (Fig. 2).

**Fig. 1.** Average annual basal area increments for moderately (solid line) and severely (broken line) damaged Scots pine by *Tomicus piniperda* near Lockport, N.Y.

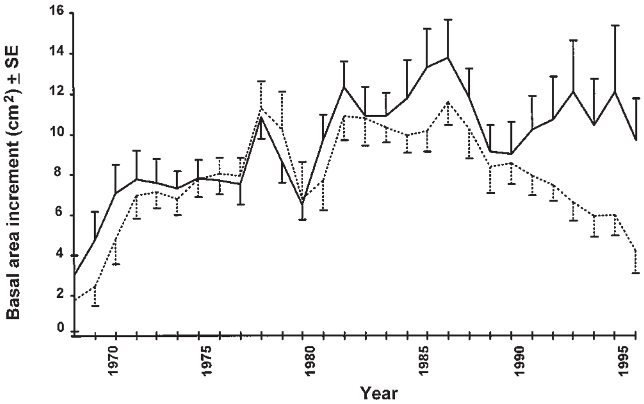
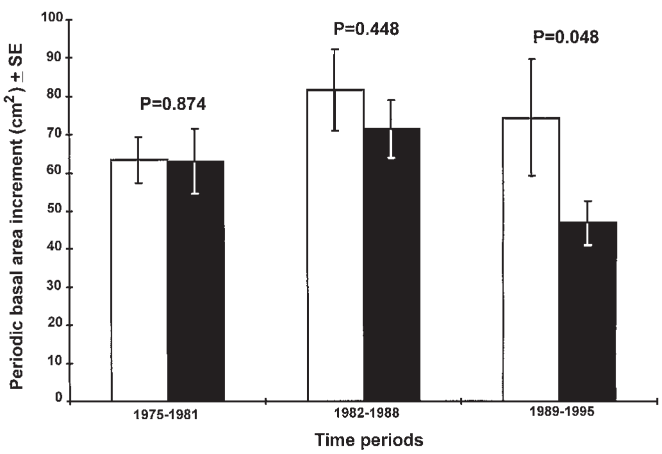


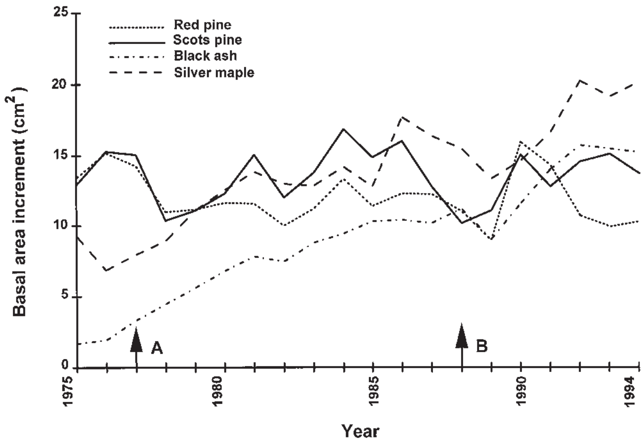

**Fig. 2.** Seven-year mean periodic basal area increments for moderately (open bars, $n = 9$) and severely (black bars, $n = 8$) damaged Scots pine by *Tomicus piniperda* near lockport, N.Y. ($t$-test on log-transformed data).




Linear regression was used to test for differences between the growth patterns of severely and moderately damaged trees. Comparisons of the 21-year series were significant for line coincidence ($P = 0.002$) and equal slope ($P = 0.002$). This indicates a significant effect associated with crown damage. However, it was apparent from the raw data that growth divergence first occurred sometime in the mid-1980's (Fig. 1). The test of line coincidence of the three 7-year series shows that lines of both damage classes were not significantly different in either the first time period (1975–1981) ($P = 0.446$) or the second time period (1982–1988) ($P = 0.318$); the slopes were also not significantly different ($P = 0.216$ and $P = 0.68$). This demonstrates that there were no differences in the growth patterns of the two damage classes prior to 1989. For the last time period (1989–1995) the test of line coincidence was significant ($P < 0.001$), as was the test for slopes ($P = 0.038$). This clearly demonstrates impact by *T. piniperda*.

In the most recent 7-year period (1989–1995) the mean periodic basal area increment of severely damaged trees was significantly less than that of moderately damaged trees ($P = 0.048$). In the two 7-year periods prior to 1989, no significant differences occurred ($P = 0.874$ and $P = 0.448$) (Fig. 2).

**Fig. 3.** Average annual basal area increments for black ash and silver maple from the study site and for Scots pine and red pine from an additional stand near Lockport, N.Y. Arrow shows severe macroclimatological changes: (A) accumulation of heavy snow in December 1977 and (B) severe drought in 1988 and 1989.




The coniferous species in the study stand and nearby stands show an abrupt decrease in radial growth in 1978 and 1979, indicating a region-wide disturbance (Fig. 3). This anomalous reduction in growth may have been caused by an adverse weather event or insect defoliation. No documented insect defoliation occurred during this period; therefore, weather events were investigated as possible causes. Heavy, wet snowfall was recorded in this area in December 1977 (NOAA 1977). This could explain the growth loss exhibited by the pine species, as breakage of lateral branches and treetops commonly occurs under those conditions. Hardwood growth patterns did not show this decrease in 1978 and 1979, as snowfall seldom causes mechanical damage (Fig. 3). This disturbance may have severely stressed or killed trees, thus increasing breeding material for *T. piniperda* in the stand. This hypothesis is uncorroborated, but it suggests a mechanism for establishment of the beetle.

The two dendrochronologies began to separate in 1982. This was followed by a visible decline in the annual increment of both damage classes after 1986, probably due to severe droughts in 1987 and 1988 (NOAA 1987, 1988) (Fig. 1). This was confirmed by tree-ring analysis of the hardwood samples, as they showed a similar growth response (Fig. 3). In 1989 the growth patterns of the two damage classes diverged again. These observations suggest that *T. piniperda* arrived in the stand possibly prior to 1982 and unquestionably before 1989.

In Europe, populations of *T. piniperda* are controlled mainly through the removal of breeding material (Hanson 1937; Nunberg 1946; Davies and King 1977; Hibberd 1991). In addition, *T. piniperda* has a large complement of natural enemies that help reduce its Eurasian population (Hanson 1937). In our study stand, no effort had been made to remove freshly dead or dying trees. Eurasian natural enemies of *T. piniperda* are absent in North American forests and only a limited number of native predators and parasitoids prey upon this exotic bark beetle (Bright 1996). In the absence of intensive sanitation and with a limited number of natural enemies, beetle densities can increase dramatically. When beetle densities are high, shoot damage increases, decreasing the photosynthetic capability of trees, eventually making them acceptable for breeding.

*Tomicus piniperda* can shoot feed on many North American *Pinus* species (Lawrence and Haack 1995). Survival of beetles feeding on shoots of hard pines (*Pinus ponderosa* Dougl. ex Laws., *P resinosa*, *Pinus banksiana* Lamb.) was higher than that on soft pines (*Pinus flexilis* James, *Pinus monticola* Dougl. ex D. Don, *P. strobus* L.). Beetles performed as well on *P ponderosa* as on *P. sylvestris*, while those feeding on *P. resinosa* performed at an intermediate level. Feeding performance on soft pines was much lower than on *P. sylvestris*. Sadof et al. (1994) demonstrated that in a mixed stand of *P. sylvestris*, *P. resinosa*, *P. banksiana*, and *P. strobus* in Indiana, *T. piniperda* preferred to shoot feed on Scots and red pines. Långström and Hellqvist (1985) and Långström et al. (1995) demonstrated that many North American pine species growing in Europe can serve as suitable hosts for *T. piniperda* reproduction and shoot feeding. Zumr (1992) demonstrated that *T. piniperda* preferred *Pinus j.* Grev. & Balf. over *P. sylvestris* for oviposition.

This is the first report of growth loss of Scots pine caused by *T. piniperda* in North America. Scots pine is not a commercial timber species but is widely planted on this continent. The damage to Scots pine estimated in this study, together with preferences for certain North American species, indicates a potential for serious damage as *T. piniperda* spreads to major pine-growing regions throughout North America.

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