# THE SPRUCE BARK BEETLE OUTBREAK IN SWEDEN FOLLOWING THE JANUARY-STORMS IN 2005 AND 2007

BO LÅNGSTRÖM, ÅKE LINDELÖW, MARTIN SCHROEDER, NIKLAS BJÖRKLUND & PETTER ÖHRN

*Department of Ecology, Swedish University of Agricultural Sciences, P.O. Box 7044, SE-75007 Uppsala, SWEDEN; bo.langstrom@ekol.slu.se*

## Introduction

In January 2005, southern Sweden was struck by the largest storm-felling that ever has been recorded in Sweden. During 8-9 January, wind speeds exceeding 30 m/s were recorded over large areas in Götaland, southern Sweden, resulting in huge areas of storm-felled forests. The Swedish Forest Agency estimated that 75 million $m^3$ had been damaged (broken or uprooted) during the storm. More than 4 million hectares were affected by the storm and 272 000 ha were classified as damaged or severely damaged. In some areas, volumes corresponding to up to 10 years annual cuts were damaged and averages volumes of damaged forests ranged from 65 to 75 $m^3$ per ha. Ca 80 % of the wind-felled trees were Norway spruce, 15 % were Scots pine and the rest, mainly broad-leaved species (Anonymous 2006).

Considering the large volumes of damaged spruce, it was clear that there was an obvious risk for subsequent outbreaks of the spruce bark beetle (*Ips typographus* L., Col. Scolytinae). Hence large efforts were made to clear up the storm-fellings as soon as possible, in order to save timber values and to prevent a build-up of bark beetle populations. As will be seen below, however, large volumes of spruce remained in the forest over the summer 2005 and some was still suitable to the beetles in spring 2006, resulting in increasing beetle populations and tree mortality.

A second storm-felling took place in partly the same area on 12 January 2007, when ca 12 million $m^3$ , mainly spruce was downed. Massive efforts were made to salvage the fallen timber before beetle flight in spring 2007, but many trees remained in the forest over the summer, producing new beetles.

This presentation summarizes the forest protection situation in southern Sweden after the January-storm 2005, i.e. we describe how the fallen trees were taken care of, how the spruce bark beetle situation has developed, and discusses some of the control measures taken to counteract tree mortality.

## Available breeding material

Figure 1 shows the estimated amounts of fallen spruce remaining in the forests at different dates after the storm-felling according to estimates by the Swedish Forest Agency. The accuracy of these estimates is not known, and all given volumes in this presentation are expressed as “$m^3$sk”. i.e. whole stem volumes including bark. In June 2005, more than half of the fallen volume remained in the forest, and much of that was still there at the end of September, despite large efforts to take care of the timber. A few million $m^3$ remained in May 2006, but the proportion of wood still suitable as breeding material is unknown. A few of those trees may still have remained fresh in spring 2007, but the majority of fallen trees in spring 2007 came from the storm in January that year. According to the estimates by the Swedish Forest Agency, ca 5 million $m^3$ of the original 12 million $m^3$ were left in spring, and ca 1.5 million $m^3$ still remained in July. In addition, ca 4 million $m^3$ of spruce were stored at temporary storage sites, some of them close to forests. In spring 2008, The Swedish Forest

Agency estimated that 1.5-3.0 million $m^3$ of mainly spruce had fallen during the winter 2008, and that ca 90% of that volume had been cleared until spring. Hence, there was only ca 0.2 million $m^3$ fresh fallen spruce during beetle flight in spring that year.

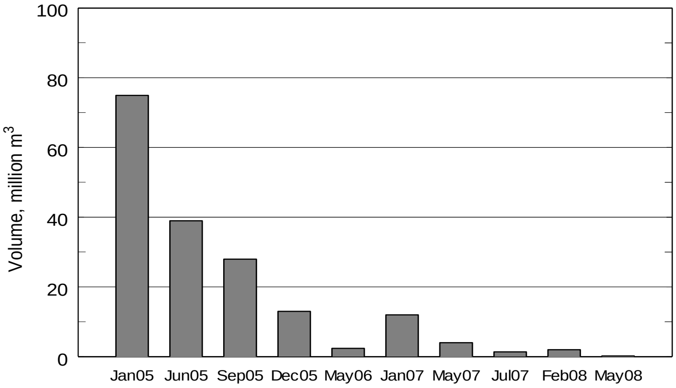


Figure 1. Estimated volumes of fresh spruce wind-falls at different dates after the storms in January 2005 and 2007 according to the Swedish Forest Agency.

**Weather conditions 2005-2008**

The temperature conditions at Asa research station, situated in the middle of the storm-felling area, during the study period are described using the thermal sum with the threshold 8 $^{o}$C (Figure 2). This is the developmental threshold for *I. typographus,* (cf. Baier et al. 2007). In all four years, the thermal sum exceeded the average for the period 1989-2007, (Ola Langvall, pers. comm.). In 2005, the early season was close to and the later part warmer than average resulting in a thermal sum of 900 dd. The early part of 2006 was cold and rainy, but the later part was exceptionally warm resulting in a total thermal sum of 1100 day-degrees, allowing two full generations of the spruce bark beetle (see below). Both 2007 and 2008 were warm and dry in the beginning, but from July onwards the weather was rainy and chilly and hence the thermal sum reached ca 900 dd, as in 2005.

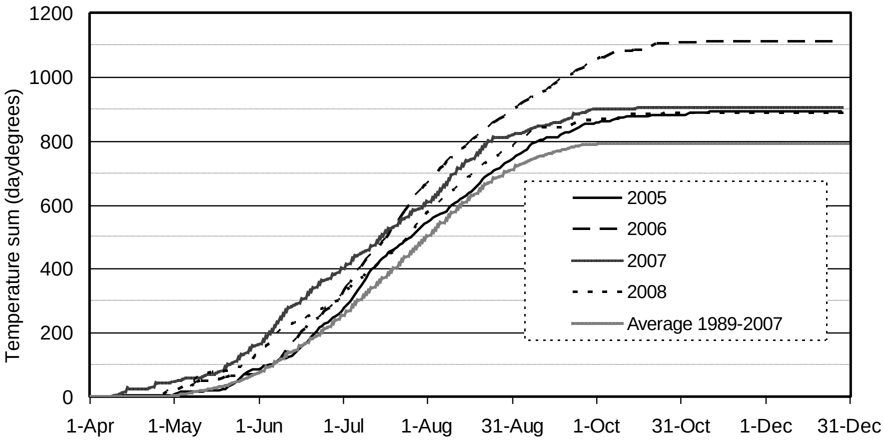


Figure 2. Weather conditions expressed as thermal sums (>8 $^{o}$C) at Asa research station in 2005-2008 and the mean for the period 1989-2007 (Ola Langvall, pers. comm.)

**Beetle activity**

In Sweden, the flight activity of the spruce bark beetle has been monitored since 1995 using pheromone traps in four regions, each consisting of five fresh clear-fellings with three pheromone traps (Lindelöw & Schroeder 2001). In 2005, the study was enlarged to include 30 additional areas in southern Sweden (Lindelöw & Schroeder 2008). Data are still being processed for 2008, and beetles flying in late season (July-August) are not included in this comparison (Figure 3). Trap catches increased from a low level in 2005 to ca 10 000 beetles (sum of three Norwegian NOVE-traps averaged over the five sites) in 2006. Catches remained at the same level in 2007, whereas a substantial increase occurred in 2008. As will be discussed below, trap catches reflect not only population density but also beetle flight activity.

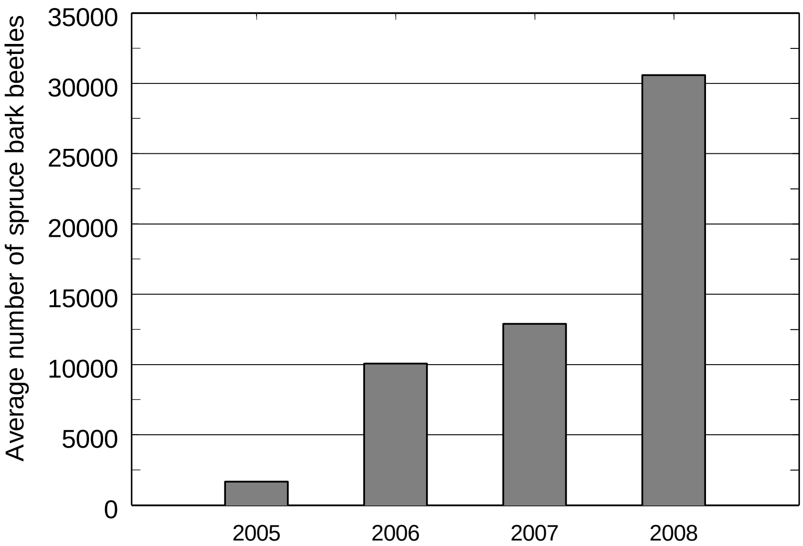


Figure 3. Average annual catches of *Ips typographus* in pheromone traps during the extended monitoring since 2005; beetles caught in pheromone traps during the main flight period in May-August in the storm area (data for 2008 based on catches from mid-April to mid-June in 32 out of the 34 areas).

Since 2005, detailed studies on the flight activity and development of *I. typographus* have been carried out at two research stations of the Swedish University of Agricultural Sciences (SLU), both situated in the storm-felling area in southern Sweden. Asa station is situated north of the city Växjö in central Småland, and Tönnersjöheden close to Halmstad at the west coast. Beetle flight was monitored using pheromone-baited window and pheromone traps (for more details, see poster presentation by Öhrn et al. in this volume). Figure 4 shows a similar increase in trap catches from 2005 to 2007 as shown above in figure 3, but the pattern differs as the in 2008. Catches before and after July 1$^{st}$ are separated in order to give a rough estimate of the proportions of beetles in the first and second generations, assuming that most of the sister-brood-flight occurred before that date. Few beetles flew after the beginning of July, except in 2006 when half and two thirds of the flight occurred after that date, at Asa and Tönnersjöheden, respectively. Data from emergence bags and bark samples (data not shown) support the conclusion that the late flight in 2006 was mainly due to second generation beetles, and in that year the thermal sum allowed a completed development of the second generation (cf. Annila 1969, Wermlinger 2004, Baier et al. 2007). In fact some callow beetles flying in late September 2006 could, at least theoretically, have been a third generation on the wings.

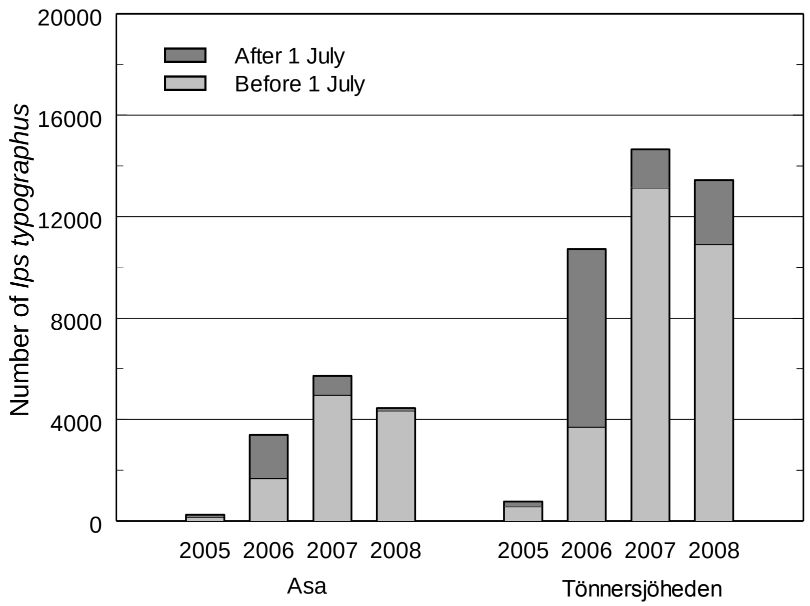


Figure 4. Catches of flying *Ips typographus* in baited window-traps at Asa and Tönnersjöheden in 2005-2008 before and after 1 July, i.e. roughly first and second generations.

**Colonisation of wind-falls and tree mortality**

Due to the low beetle population in spring 2005 (cf. Lindelöw & Schroeder 2008), and the abundance of breeding material, only a fraction of the fallen trees were colonized by the spruce bark beetle. Different estimates indicate that less than 5 % and on average 2.4 % of the wind-falls were colonised by *I. typographus* (Anonymous 2007). Thus, ca 0.9 million $m^3$ (39 x 0.024) spruce trees was attacked during 2005 (Figure 5), and ca 80 % of that volume remained in the forest over the summer, and may hence have produced offspring during that year. Virtually no attacks on standing trees were recorded in 2005.

In 2006, many remaining fallen spruces were still fresh, and according to the National Forest Inventory (NFI) ca 60 % the fallen trees were attacked by *I. typographus* (S. Wulff pers. comm.). That means that ca 1.4 million $m^3$ (60% of 2.4 million) may have been colonised by the beetles in that spring according to the Swedish Forest Agency, while NFI estimated that the attacked volume during 2006 was 1.02 million $m^3$ ± 36% (S. Wulff pers. comm.). Few attacks were seen on standing trees in early summer, but the intense beetle flight in late summer resulted in ca 1.5 million $m^3$ of beetle-killed spruce in that year, according to estimates made by the Swedish Forest Agency. The second generation probably played an important role in these attacks, although only one third of the new generation took part in the flight (estimate based on the presence of exit holes in bark samples taken during July and August at the research stations).

In 2007, the National Forest Inventory estimated that 31 % of the fallen spruces were colonised by the spruce bark beetles, and that the attacked volume was 1.3 million $m^3$. According to the Swedish Forest Agency, ca 0.8 million $m^3$ of standing spruce was killed by the beetles this year. This damage was lower than expected considering the high beetle population in spring resulting from the two generations produced in the previous year. Most of the damage occurred in early summer during the main flight period (Figure 4). From July onwards, the rainy and chilly weather lead to reduced beetle flight activity but also, and probably more important, to increased tree vigour and hence to fewer successfully colonised trees.

The year 2008 was similar to the previous one, i.e. warm and dry early summer and chilly and wet late summer. As there were few fresh fallen spruce trees, the beetles had to attack standing trees. The estimates by The Swedish Forest Agency indicate a small decline in tree mortality as currently ca 700 000 $m^3$ are reported to have been killed by beetle attacks in 2008.

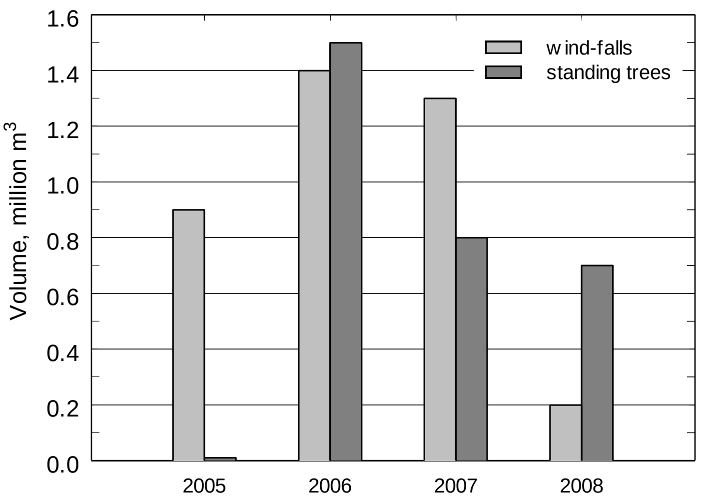


Figure 5. Fallen and standing volumes of spruce attacked by *Ips typographus* in 2005-2008 according to estimates by the Swedish Forestry Agency.

**Control activities**

Immediately after the storm-felling in 2005, it became obvious that there was an imminent risk for bark beetle outbreaks. In 2005 and 2006, all efforts were focussed on clearing up the storm-felled areas in order to save the timber and to reduce the breeding material for the beetles. Late in 2006, a control strategy was adopted with the main focus on finding, cutting and removing beetle-colonized trees in the summer, autumn and winter. Cutting in winter was also recommended, as about half of the beetles were observed to hibernate in the trees (Anonymous 2007). As scenario models indicated that large tree volumes were at danger of being beetle-killed (Anonymous 2007), it was considered impossible to clear all attacked trees in due time, and hence other options had to be taken into consideration. As the experiences from the previous mass-trapping campaign using pheromone traps in Sweden and Norway in the late 1970s (Bakke 1989, Weslien 1992) and later attempts to use pheromone traps for beetle control (for an overview, see Wermlinger 2004) had not been very convincing, some forest companies decided to use a method based on trap logs baited with pheromones and sprayed with insecticides that had been developed in Central Europe (for overview and references, see Faccoli & Stergulc 2008) Altogether some 15 000 traps log piles and some 25 000 pheromone traps were used in 2007 according to statistics collected by the Swedish Forest Agency. The efficiency of the trap-log-piles has been questioned and studies are in progress to compare the trapping efficiency between these and pheromone traps (see abstract by Björklund et al. in this volume). Preliminary analysis of the data from 2007 indicate that the trapping efforts had little effect on local tree mortality, i.e. in the vicinity of the traps, but larger studies this year also address the issue on a larger scale.

**Discussion**

The current outbreak of the spruce bark beetle in Sweden has so far followed a typical pattern that has been repeatedly observed after major storm-felling events in Sweden (e.g. Trägårdh & Butovitsch 1935, Eidmann 1983, Schroeder & Lindelöw 2002) and elsewhere in Europe (e.g. Wermlinger 2004, Grodzki et al. 2006, Forster & Meier 2008). Typically, the beetle population increases in the fallen trees during the first season, and then attacks on standing trees occur during a few years before the outbreaks fades out. Prolonged outbreaks, lasting up to a decade or even longer, may occur when storm-fellings are followed by exceptionally dry weather conditions leading to an abundance of draught-stressed trees, like in Norway and Sweden in the 1970s (Eidmann 1983, Worrell 1983) and in e.g. Germany (Baden-Württenberg) in the 1990s (Schröter 2004). Thus, we expect the current outbreak to fade out in a few years, unless new host material of low vigour becomes available through exceptionally dry weather conditions, or new storm-fellings.

In Sweden, the beetle-related tree mortality has always been only a fraction (< 10%) of the storm-felled volumes (e.g. Trägårdh & Butovitsch 1935, Eidmann 1983), but in Central Europe relatively more trees may die in subsequent beetle outbreaks (e.g. Forster et al. 2003, Grodzki et al. 2006). Considering the volumes of storm-felled spruce trees in 2005 and 2007, the resulting tree mortality so far has been lower than was anticipated after the large population build-up especially in 2006. Altogether some 3 million $m^3$ have been killed during three years (Figure 5) which is of the same magnitude as during the 1970s (Eidmann 1983, Risberg 1985). These estimates are, however, not very accurate, as they rather are based on estimates than systematic field The 800 000 $m^3$ presented in figure 5 is the "official" figure reported by the Forest Agency, while the National Forest Inventory gives an estimate of 462 000 $\pm$ 141 000 $m^3$ (S. Wulff, pers. comm.) and the forest company Södra AB concludes that the figure should be ca 1.2 million. This range in estimates is problematic, and more efforts should be made to use a systematic and nationwide system for estimating tree mortality (and other forest damage effects).

When comparing the trap catches (Figure 3) and tree mortality (Figure 5), it is obvious that these two estimates do not match very well. It has earlier been shown that tree mortality tends to increase above a threshold of ca 10 000 beetles per group of three traps (Weslien et al. 1989, Lindelöw & Schroeder 2001), but also that there is a large variation in tree mortality at a given trap catch level. We believe that this reflects differences in tree vigour between years and sites. In addition, as trap catches depend, not only on beetle numbers, but also on beetle flight activity and the presence of other pheromone sources in the landscape, these factors have to be considered when evaluating trap catches versus tree mortality. In 2005, trap catches were expected to be very low because of a low beetle population (cf. Lindelöw & Schroeder 2008) and an abundance of fallen spruce trees attracting beetles and thus acting as competing pheromone sources. In 2006, higher trap catches reflected the increased beetle population that was produced in the fallen trees in 2005, and the development of two generations resulted in substantial tree mortality in 2006 and an even higher hibernating beetle population. Trap catches did, however, remain at the same level in 2007 while tree mortality went down. In contrast, trap catches more than doubled in 2008 despite decreasing tree mortality. These differences in trap catches may be linked to the different availability of wind-felled trees acting as competing pheromone sources in different years. In 2007, there were more wind-falls attracting beetles than in 2006, and in 2008 there only few wind-falls, which may have lead to increased flight activity resulting in the larger trap catches in 2008.

Considering the proportions of attacked fallen and standing volumes in 2006 and 2007, it becomes obvious that the fallen trees in 2007 attracted a substantial number of beetles, and probably saved a large number of standing trees from attacks in that year. The effect of the second storm-felling on the population size is, however, unclear as we do not yet know how much of the brood was destroyed in due time to prevent beetle emergence during the further handling of the trees. Further analyses on factors affecting the dynamics of the outbreak are in progress and will be reported later.

Three of the four study seasons displayed local thermal sums well above the calculated average (cf. Figure 1), and in general the last decade has been warmer than the long-term average (Jönsson et al. 2007). If this trend reflects a general global warming, there is an obvious risk that bark beetle problems will increase in northern Europe as the spruce bark beetle will become bivoltine and tree vigour will be affected by changed precipitation patterns. In addition, as there seems to be accumulating evidence that bark beetle outbreaks cannot really be controlled by human countermeasures, a deeper understanding of the population dynamics of bark beetles is essential in order to learn to cope with future outbreaks in the best possible way.

**Acknowledgements**
We thank the Swedish Forest Agency for funding support in all study years and FORMAS, SLU and Södra's stiftelse for support during the first year. We also thank the staff at the district offices participating in the beetle monitoring program as well as the staff at the research stations for technical assistance.

**References**

ANNILA, E. 1969. Influence of temperature upon the development and voltinism of *Ips typographus* L. (Coleoptera: Scolytidae). *Ann. Zoo.l Fenn.* 6, 161-207

ANONYMOUS. 2006. Stormen 2005 – en skoglig analys. *Meddelande* 1, 2006, The Swedish Forest Agency, Jönköping. (In Swedish).

ANONYMOUS. 2007. Övervakning av insektsangrepp – slutrapport från Skogsstyrelsens regeringsuppdrag. *Meddelande* 1, 2007, The Swedish Forest Agency, Jönköping. (In Swedish).

BAKKE, A. 1989. The recent *Ips typographus* outbreak in Norway - experiences from a control program. *Holarctic ecology* 12, 515-519.

BAIER, P., PENNERSTORFER, J. & SCHOPF, A. 2007. PHENIPS—A comprehensive phenology model of *Ips typographus* (L.) (Col., Scolytinae) as a tool for hazard rating of bark beetle infestation. *For. Ecol. Manage*. 249, 171-186.

EIDMANN, H.H., 1983. Management of the spruce bark beetle *Ips typographus* in Scandinavia using pheromones. *International congress of plant protection 10 Brighton 1983*, 1042-1050.

FACCOLI, M. & STERGULC, F. 2008. Damage reduction and performance of mass trapping devices for forest protection against the spruce bark beetle, *Ips typographus* (Coleoptera Curculionidae Scolytinae) *Ann. For. Sci.* 65:309.

FORSTER, B.& MEIER, F. 2008. Sturm, Witterung und Borkenkäfer - Risikomanagement im Fortsschutz. *WSL, Merkblatt für die Praxis* 44, 1-8.

FORSTER, B., MEIER, F., GALL, R. & ZAHN, C. 2003. Erfahrungen im Umgang mit Buchdrucker-Massenvermehrungen (*Ips typographus* L.) nach Sturmereignissen in der Schweiz. *Schwez. Z. Forstw.* 154, 431-436.

GRODZKI, W., JAKUŠ, R., LAJZOVA , E., SITKOVA, Z., MACZKA, T. & SKVARENINA, J. 2006**.** Effects of intensive versus no management strategies during an outbreak of the bark beetle *Ips typographus* (L.) (Col.: Curculionidae, Scolytinae) in the Tatra Mts. In Poland and Slovakia. *Annals of Forest Science* 63, 55-61.

JÖNSSON, A.M., HARDING, S., BÄRRING, L. & RAVN, H.P. 2007. Impact of climate change on the population dynamics of *Ips typographus* in southern Sweden. *Agr. For. Meteorology* 146, 70-81.

LINDELÖW, Å. & SCHROEDER, M. 2001. Spruce bark beetle, *Ips typographus* L., in Sweden: monitoring and risk assessment. *Journal of Forest Science* 47: 40-42.

LINDELÖW, Å. & SCHROEDER, M. 2008. The storm "Gudrun" and the spruce bark beetle in Sweden. *Forstschutz Aktuell* 44, 5-7.

RISBERG, B. 1985. Uppskattning av granbarkborreskador i Värmland 1971-1982 genom korrigering och komplettering av tidigare flyginventeringsresultat. (Summary: Estimation of *Ips typographus*-damage in Värmland 1971-1982 by correcting and supplementing earlier results from sketch mapping). *Sveriges Skogsvårdsförbunds Tidskrift* no 2, 21-31.

SCHROEDER, L.M. & LINDELÖW, Å. 2002. Attacks on living spruce trees by the bark beetle *Ips typographus* (Col. Scolytidae) following a storm-felling: a comparison between stands with and without removal of wind-felled trees. *Agr. For. Ent.*, **4**, 47-56.

SCHRÖTER, H.J. 2004. Waldschutzprobleme nach Lothar. *Schriftenreihe der Landesforstwerwaltung Baden-Württenberg* 83, 341-370.

TRÄGÅRDH, I., & BUTOVITSCH, V. 1935. Redogörelse för barkborrekampanjen efter stormhärjningarna 1931-1932. (Bericht über die Bekämpfungsaktion gegen Borkenkäfer nach den Sturmverheerungen 1931-1932). *Medd. Statens Skogsförsöksanstalt* 28, 268 pp.

WERMLINGER, B. 2004. Ecology and management of the spruce bark beetle *Ips typographus* - a review of recent research. *For. Ecol. & Manage.* 202, 67-82.

WESLIEN, J. 1992. Effects of masstrapping on *Ips typographus* (L.) populations. *J. Appl. Entomol.* 114: 228-232.

WESLIEN, J., ANNILA, E., BAKKE, A., BEJER, B., EIDMANN, H.H., NARVESTAD, K., NIKULA, A., & RAVN, H.P. 1989. Estimating risks for spruce bark beetle (*Ips typographus* (L.)) damage using pheromone-baited traps and tree. *Scand. J. For. Res.* 4, 87-98.

WORRELL, R. 1983. Damage by the spruce bark beetle in South Norway 1970-1980. A survey and factors affecting its occurrence. *Medd. Nor. Inst. Skogforsk.* 38(6), 1-34.