Infestations of the cypress bark beetles *Phloeosinus rudis*, *P. bicolor* and *P. thujae* in The Netherlands (Coleoptera: Curculionidae: Scolytinae)

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KEY WORDS
Cupressaceae, drought stress, invasive species, northwards shift, pest insects

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In the summer of 2004, hundreds of shrubs and trees of Cupressaceae in The Netherlands were killed by the Japanese cypress bark beetle, *Phloeosinus rudis*. Dead trees with larval galleries under the bark were observed in several cities near Rotterdam. The infestations of this invasive species occurred in old solitary *Thuja* trees as well as in younger plants of *Thuja*, *Chamaecyparis* and *Juniperus* in hedges. In the period 2005 until 2008, only few infestations were reported. It is suspected that *P. rudis* may have escaped from imported material from the harbour of Rotterdam. In addition, the Mediterranean cypress bark beetles *Phloeosinus bicolor* and *Phloeosinus thujae* were identified as well as the cause of death of many Cupressaceae on several locations in 2004. The latter two species are moving their range northwards. In the past, *P. thujae* has been reported a few times while *P. bicolor* was found for the first time in The Netherlands. It seems no coincidence that the three *Phloeosinus* species caused large scale attacks in the same year: the severe drought of 2003 possibly made the trees susceptible for bark beetles. For Western-Europe, the climate change models predict increasing summer drought and heat waves, which make trees vulnerable for secondary pest insects such as *Phloeosinus* species. In the future we may expect more trees to be weakened and by that, more infestations by secondary pests and diseases.

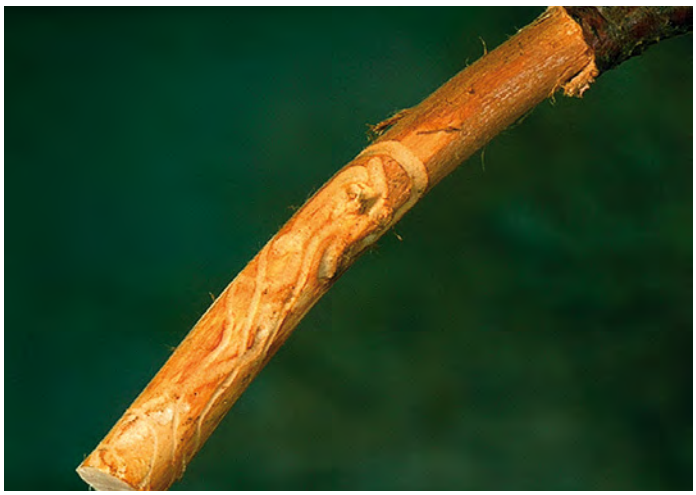
Introduction

Bark beetles (Coleoptera: Curculionidae: Scolytinae) are among the most damaging tree pests, because the adults and larvae are tunnelling beneath the bark and kill the tree by their girdling. Most bark beetles breed in trees weakened by drought, defoliation by insects or diseases and in fresh felled trees (Lieutier 2004, Rouault *et al*. 2006, Schwenke 1974). Species of the genus *Phloeosinus* excavate their galleries under the bark of trunks and branches of weakened Cupressaceae such as *Chamaecyparis*, *Cupressus*, *Thuja* and *Juniperus*. Species of these plant genera are not indigenous in Europe with the exception of *Juniperus communis*. Many bark beetle species have been invasive to other continents because they are easily transported inside wooden products, wood packaging materials, nursery stock and bonsai trees (Brockerhoff *et al*. 2006, Haack 2006). In 2004, three *Phloeosinus* species caused heavy infestations on Cupressaceae in The Netherlands. In this article, information is given on their biology and occurrence.

Biology of *Phloeosinus* species

Phloeosinus species breed usually in branches and logs of fresh felled and fresh dead trees, but they also breed in living trees which are weakened by drought, fire or diseases (Schwenke 1974). The adult beetles invade through the bark and excavate their brood galleries in which the eggs are laid. The larval feeding tunnels (figure 4) end in pupal chambers inside the bark. Depending on the species and geographic climate, there are 1-2 generations per year (Schwenke 1974). For additional nourishment (maturation feeding) and their hibernation, in the tree, the newly emerged adults tunnel into the axils of twigs on healthy trees, and may cause some damage by twig pruning (figures 1, 2). The dead brown twig tips, called flags, often remain on the trees. This flagging is not an indication that the tree is not healthy, but that somewhere in the area, there is a dead or dying tree serving as a breeding place for the beetles. Under a more intensive attack, the number of dead shoots is very high. The attacked plants grow less vigorously, weaken physiologically and lose their ornamental appearance. The European *P. bicolor* and *P. thujae* are small beetles and they infest predominantly younger plants. The Japanese *P. rudis* however,

1. Starting maturation feeding of adult *Phloeosinus rudis*. Photo: Leen Moraal
1. Beginnende rijpingsvraat door een adulte *Phloeosinus rudis*.



2. Maturation feeding of adult *Phloeosinus thujae* in a small branch. Photo: Alterra / A. van Frankenhuyzen
2. Rijpingsvraat door een adulte *Phloeosinus thujae* in een dunne tak.

is larger and is able to kill large mature trees. For the identification keys on *Phloeosinus* can be referred to Balachowsky (1949) and Pfeffer (1995). Information on the biology can be found in Schwenke (1974) and Sobczyk & Lehmann (2007).

Phloeosinus rudis Blandford, 1894

In The Netherlands, insect pests on trees are annually being monitored by a network of tree managers all over the country, and this is coordinated by Alterra. During the summer of 2004 it was observed that more then 300 conifers died in the city of Ridderkerk (province of Zuid-Holland). Solitary trees as well as complete hedges (figure 3) felt victim to this pest species. The plants turned brown and showed symmetric larval galleries under the bark with young beetles leaving their exit holes (Moraal 2005a, 2005b). The length of the 2-3 armed egg galleries varied from 5-16 cm (figure 4). The diameter of the exit holes varied from 1.1-1.9 mm (figure 5). Several conifer species of different ages were killed, for example a solitary 60-year-old *Thuja occidentalis*, a 25-year-old *Chamaecyparis lawsoniana* and a 20-year-old *Juniperus chinensis*. Furthermore, hundreds of conifers died, for example in the cities of Maassluis, Hazerswoude, Nieuw-Lekkerland, Dordrecht, Rotterdam (all Zuid-Holland), and Sleeuwijk (Noord-Brabant). Many unidentified garden conifers died and were removed by their owners. It was remarkable that during the summer of 2004, large quantities of dead conifers were delivered for destruction to city garbage dumps (personal communication R. Demuijnck).

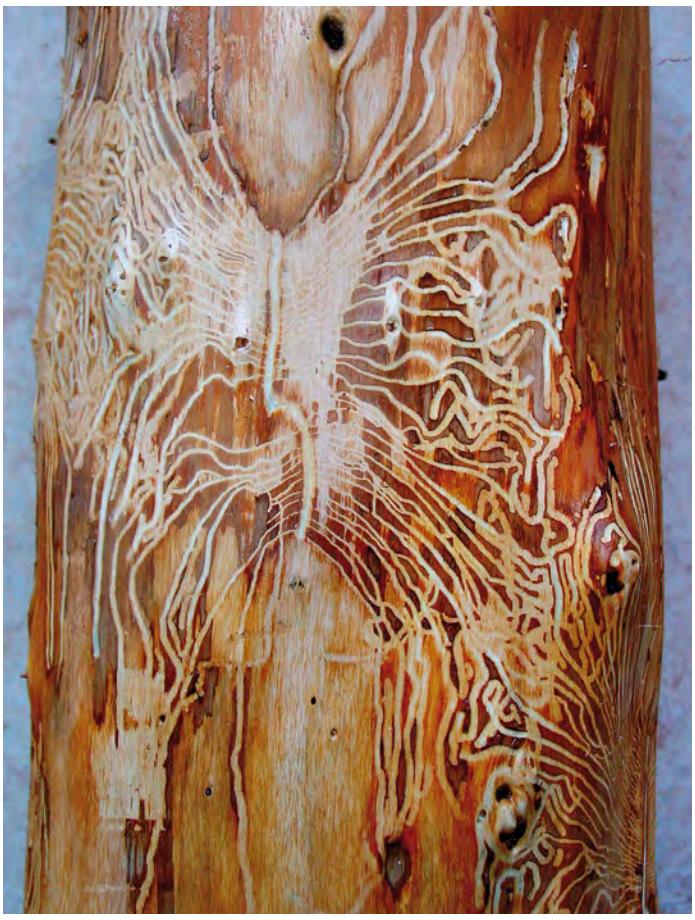
The cause of these destructions was an infestation of dark-brown beetles (figure 6), later identified as *Phloeosinus rudis*; a species originating from Japan. For detailed information on the beetle's morphology and origin can be referred to Balachowsky (1949), Hoffmann (1942) and Pfeffer (1995).

In 2004, the year of the first infestations, all records from the Alterra monitoring project are situated within a range of about 30 km from the harbour of Rotterdam (figure 8). Therefore it was suspected, that *P. rudis* may have escaped from imported material from this harbour, but this could not be verified. In the USA, the beetle was intercepted several times in wood dunnage material used for transport of steel products from Asia, but there are no recordings of establishment over there (Haack 2001, 2006). The first record of *P. rudis* outside Asia was made in France near Saint-Tropez in 1940. The beetle was found in small numbers in dying branches of *Thuja japonica* of an experimental forest site (Hoffmann 1942). However, the beetle has not been recorded there since (personal communication T. Noblecourt and L.-M. Nageleisen, INRA France, 2004).

I observed that the Japanese *P. rudis* is able to kill mature trees while the European *P. bicolor* and *P. thujae* only infest smaller and younger plants. General information on the biology of *Phloeosinus* species is given hereafter.

In The Netherlands, only a few infestations were reported since 2004. This is probably due to the normal summer precipitation of the following years, which led to vigorous plants that are less susceptible. In July 2005, an infestation of a 46-year-old solitary *Thuja* in Nieuw-Loosdrecht (province of Noord-Holland) was discovered. In 2007, an 80-year-old *Chamaecyparis obtusa* in an arboretum at Rotterdam suffered from a fungal infection at the base of the trunk. After removal of the bark, hundreds of adult beetles were found. In January 2008, many living larvae (figure 7) and some adults were found overwintering inside the bark of an old *Thuja* in Rotterdam. Four years after its first discovery, *P. rudis* was still present in The Netherlands. Small beetle populations may survive here in weakened trees. This implies that a new drought period may lead again to many stressed trees, resulting in the beetle's population built-up and by that a significant mortality of trees. This relation between drought and *Phloeosinus* infestations is also mentioned by other authors (e.g., Hayes *et al.* 2008, Bel Habib *et al.* 2007, Schwenke 1974). From several observations on material during 2003 and 2008 from Ridderkerk and Rotterdam, it can be concluded that *P. rudis* overwinters dominantly in the larval stage with one generation per year in The Netherlands. In 2008, infestations of *P. rudis* (together with *P. thujae*) were found at a location in Wageningen and in Renkum in broken branches of a small *Chamaecyparis* and an unidentified small Cupressaceae shrub (Th. Heijerman personal communication). These locations are more remote, about 50 km in a straight line, from the boundaries of the Rotterdam area in 2004.

3. Hedge of *Chamaecyparis* with dead shrubs infested by the Japanese cypress bark beetle, *Phloeosinus rudis*. Photo: Leen Moraal
3. Heg van *Chamaecyparis* met dode struiken aangetast door de Japanse thujabastkever, *Phloeosinus rudis*.



4. Trunk of 60-year-old *Thuja* with the longitudinal egg gallery and transversal larval galleries of *Phloeosinus rudis*. Photo: Leen Moraal
4. Stam van een 60-jarige *Thuja* met het broedbeeld van *Phloeosinus rudis*, een verticale moedergang met horizontaal uitwaaierende larvengangen.

Phloeosinus bicolor Brullé 1832 (syn. *P. aubei* Perris 1855)

An infestation of *P. bicolor* was found in 2004 at Arcen (province of Limburg) in a 20-year-old hedge with *Chamaecyparis*. In the same year, infestations were also found in *Chamaecyparis* at Sint-Oedenrode and Roosendaal (both Noord-Brabant) and in *Thuja* at Krimpen aan de Lek (Zuid-Holland) (figure 8). It was the first record of this beetle in The Netherlands. *Phloeosinus bicolor* can breed in *Juniperus*, *Thuja* and *Chamaecyparis* (Sobczyk & Lehmann 2007). This beetle produces longitudinal two-armed egg-galleries with a length of 2-6 cm in the longitudinal direction of the stem or branch. The transverse larval tunnels end in pupal cells which mainly lie in the bark. In Germany, the overwintering occurs in the adult stage with presumably one generation per year (Sobczyk & Lehmann 2007).

The beetle is common in the Mediterranean region, e.g., the southern part of France, Spain, Algeria, Greece, Italy, Morocco, and Lebanon (Balachowsky 1949). In the Kessra mountain area in Tunisia, two generations per year with three sister broods are reported (Bel Habib *et al.* 2007). In the past, the northern border of its range in Europe was located in Austria and Slovakia (Pfeffer 1995). During the last 50 years, some populations existed north of the Alps in Southern Germany. Recently, the beetle is shifting northwards in Eastern Germany in gardens and nurseries on *Juniperus chinensis*, *J. horizontalis* and *Chamaecyparis lawsoniana* (Sobczyk & Lehmann 2007). This expansion is most likely related with trading of infested nursery plants because active flight dispersal of *P. bicolor* over a large area was not observed (Sobczyk & Lehmann 2007). In 1996, the beetle was also reported from Britain in a dead *Thuja plicata*; one year after the tree was imported from Italy. So, the beetles have been present for at least one year before discovery and it is possible that the beetle bred and dispersed locally (Winter 1998).

Phloeosinus thujae (Perris, 1855)

In 2004, infestations of *P. thujae* were observed in the Dutch cities of Veenendaal (Gelderland, in a hedge of *Juniperus chinensis*), Nijmegen (Gelderland, hedge with unidentified conifers), Doetinchem (Gelderland, 15-year-old *Thuja*), Venray (Limburg, hedge of *Chamaecyparis*) and in *Thuja* at Boskoop (Zuid-Holland) (figure 8). For *P. thujae*, the host plants are *Juniperus* and *Thuja* (Pfeffer 1995). The adults make longitudinal two-armed egg-galleries with a length of 2-4 cm in the longitudinal direction of young stems and small twigs. Depending of the climatic conditions, there are 1-2 generations per year (Schwenke 1974). The initial distribution of *P. thujae* is Southern-Europe and North-Africa. It is remarkable that this species is shifting northwards in Germany in recent years (Sobczyk & Lehmann 2007). The beetle was also found on *Thuja orientalis* at Kew Gardens in England in 1922. It has established since and breeds in various Cupressaceae in southern England (Winter 1998). In The Netherlands, the first discovery of *P. thujae* was in 1934 at Ommen (Overijssel) in *Juniperus*. The second finding was in 1962 in *Thuja* in a forest near Hapert (Noord-Brabant) (Doom 1964).

Prevention of damage

Phloeosinus species are attracted to weakened shrubs and trees by changes in secondary plant metabolites (Hayes *et al.* 2008). Keeping the plants in good condition by pruning dead branches and giving water in dry summers, may help against infestations. At Ridderkerk it was observed that one hedge with *Chamaecyparis* died due to *P. rudis*, while an adjacent hedge with the same plants survived. This was apparently because the latter has been given water by the owner during the drought of 2003. To prevent infestations in nurseries, gardens and public green areas, it is recommended to remove all the weak plants which are suitable for the beetles. Burning of infested plants may prevent the build-up of beetle populations.

5. Exit holes of young *Phloeosinus rudis* beetles. Photo: Leen Moraal
5. Uitvlieggaatjes van jonge *Phloeosinus rudis* kevers.

Natural enemies

In the absence of natural enemies and indigenous competitors, exotic introduced insects may cause more damage in Europe than in their native range. It is therefore important to have good regulations for inspection and monitoring of imported plants and their products (Roques *et al*. 2006). However, for the exotic *P. rudis* infestation on *Juniperus chinensis* at Ridderkerk in 2004, we have found a natural enemy. We reared 12 specimen of the parasitoid *Rhaphitelus maculatus* Walker 1834 (Pteromalidae) from this material. Kenis *et al*. (2004) mention this larval ectoparasitoid (and 11 other parasitoid species) for the European *Phloeosinus armatus*, *P. bicolor* and *P. thujae*. Parasitoids will have their impact on the beetle populations, but their impact is unknown.

Exotic threat for indigenous plants?

Juniperus communis is a protected indigenous shrub species in The Netherlands, mainly growing on heath lands in nature reserves. Until now, no infestations of *P. rudis* were found on this shrub in The Netherlands. In Germany, *P. bicolor* and *P. thujae* seem not to be able to disperse over a large area, because the infestations occur only locally in certain cities. The wild *Juniperus communis* grows far away from cities and seems here not really endangered (Sobczyk & Lehmann 2007). However, in North-America it was demonstrated that *Phloeosinus chamberlini* Blackman 1942, had dispersed over about 24 km (Furniss & Furniss 1972). The widespread infestations in 2004 about 30 km around Rotterdam also suggest that *P. rudis* may have a good active dispersal capacity and it may not be excluded that it may colonize heath lands from infested urban areas in the long run. It remains unclear what the impact of *P. rudis* on *J. communis* will be.

6. Adult of *Phloeosinus rudis*. Photo: Theodoor Heijerman
6. Een adult van *Phloeosinus rudis*.

Effects of drought and climate change

In The Netherlands, insect pests on trees are annually being monitored annually since 1946. During the last decades, northward shifts of Mediterranean species are observed. Climate change is one of the most likely drivers (Moraal 2007, 2009, Moraal & Jagers op Akkerhuis 2008, Verkaik *et al*. 2009). For *P. thujae* and *P. bicolor* it is not known if their current distribution is the result of trading or the result of an autonomous northwards migration. The occurrence of the Japanese *P. rudis* in The Netherlands is most likely due to trading of plants or wood products. However, there is a link between climate change and invasive alien species. The new climatic conditions may give a chance to insect species, which would not have chances before. In Europe, heat and drought were extreme during the summer of 2003. It is highly probable that this is related with global climate change (Fink *et al*. 2004, Rebetez *et al*. 2006, Verkaik *et al*. 2009). Drought during the growing season may cause severe plant-stress and conifers may become susceptible for bark beetle attacks. In stressed conifers, resin flow and concentrations of secondary metabolites are reduced, and by that, the physical and chemical resistance to bark beetles (Rouault *et al*. 2006). Beetles may occasionally built-up their populations in weakened trees. They become more numerous and aggressive and able to attack and kill apparently healthy trees. When climate change will result in more hot and dry summers, we must be alert on increasing numbers of secondary pests which may take advantage of trees and shrubs weakened by drought (Rouault *et al*. 2006).

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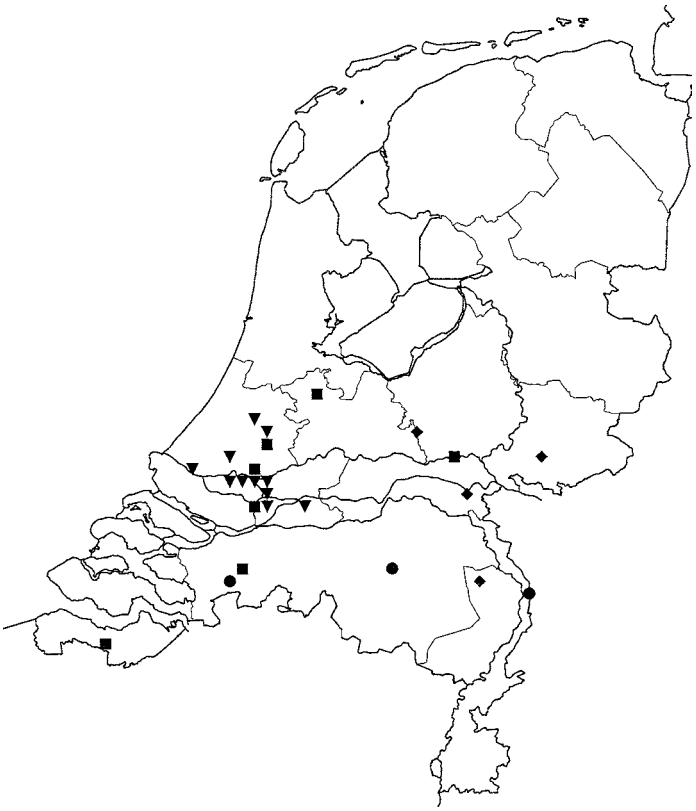
7. Overwintering *Phloeosinus rudis* larvae in the bark. Photo: Leen Moraal
7. Overwinterende *Phloeosinus rudis* larven in de bast.



8. Records of infestations by *Phloeosinus rudis* (▼), *P. thujae* (◆), *P. bicolor* (●) and *Phloeosinus* spec. (■ - unidentified *Phloeosinus* species) in 2004 as derived from the Alterra monitoring scheme. Not all records are visible, due to some overlap in sites for the separate species.
8. Waarnemingen uit het Alterra monitoringsproject van aantastingen door *Phloeosinus rudis* (▼), *P. thujae* (◆), *P. bicolor* (●) en *Phloeosinus* spec. (■ - ongeïdentificeerde *Phloeosinus* soorten) in 2004. Niet alle waarnemingen zijn zichtbaar door overlap in enkele vindplaasten van de verschillende soorten.

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Samenvatting

Aantastingen door de thujabastkevers *Phloeosinus rudis*, *P. bicolor* en *P. thujae* in Nederland (Coleoptera: Curculionidae: Scolytinae)

In de zomer van 2004 trad er grote sterfte op bij coniferen in Rotterdam en nabijgelegen steden zoals Ridderkerk, Sleeuwijk, Maassluis, Nieuw-Lekkerland en Dordrecht. De sterfte trad op bij een solitaire 60-jarige *Thuja* maar ook bij coniferenhagen van *Thuja*, *Chamaecyparis* en *Juniperus*. Onder de schors werden uitgebreide gangenstelsels en kevertjes aangetroffen. In de schors zaten duizenden kleine ronde gaatjes. De kever werd gedetermineerd als *Phloeosinus rudis*. Het betreft een van oorsprong Japanse keversoort die nooit eerder in Nederland is aangetroffen. Gezien de locaties in en rond Rotterdam is deze exoot mogelijk via de Rotterdamse haven ons land binnengekomen. Na 2004 werd de kever nog maar enkele malen waargenomen. Kleine populaties kunnen echter overleven in verzwakte bomen zoals in 2008 bleek uit de vondst van kevers in een door parasitaire schimmels verzwakte boom (Rotterdam) en gebroken takken (Wageningen en Renkum). Er kan dus nog een kleine populatie aanwezig zijn waaruit, bij een nieuwe droogteperiode, opnieuw een populatieopbouw kan optreden. In 2004 werden eveneens veelvuldig aantastingen van de Europese thujabastkevers *Phloeosinus bicolor* en *Phloeosinus thujae* bij jongere planten van *Chamaecyparis*, *Thuja* en *Juniperus* waargenomen. De beide Mediterrane keversoorten laten de laatste jaren een noordwaartse verspreiding zien. Voor Nederland zijn van *P. thujae* uit het verleden slechts enkele waarnemingen bekend, van *P. bicolor* gaat het om de eerste waarneming. Tot nu is er geen sterfte bij de inheemse jeneverbessen waargenomen.
De relatief grotere Japanse *P. rudis* is in staat om zowel jonge als ook oude bomen aan te tasten terwijl de kleinere Europese *P. thujae* en *P. bicolor* in het algemeen bij jongere struiken voorkomen. Het massaal tegelijkertijd optreden van de drie keversoorten in 2004, is niet toevallig. Het zijn zwakteparasieten die zich alleen in verzwakte bomen kunnen ontwikkelen. 2003 was een zeer droog jaar met veel door droogtestress verzwakte bomen en struiken waardoor de aantastingen konden plaatsvinden. De huidige klimaatmodellen voorspellen voor West-Europa en toename van zomerdroogte en hittegolven. We zullen in de toekomst rekening moeten houden met meer gestreste bomen en toename van secundaire ziekten en plagen.

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