Ecologica Montenegrina
ISSN 2336-9744 (online) | ISSN 2337-0173 (print)

Ecologica Montenegrina 81: 119-125 (2025)
This journal is available online at: www.biotaxa.org/em
https://dx.doi.org/10.37828/em.2025.81.16

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Infestation of *Pityokteines curvidens* (German, 1823) (Curculionidae: Scolytinae) in Silver fir Forests of Molise (Southern Italy)

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Received 5 January 2025 | Accepted by *V. Pešić*: 4 February 2025 | Published online 7 February 2025.

Italian forests are facing increasing challenges related to various disturbances, including declines caused by pathogens and insect pests (Papitto *et al.* 2018; Rizzo & Gasparini 2022; Forzieri *et al*. 2023), which are driven by environmental factors such as climate change and forest fragmentation (Lieutier *et al.* 2016).

In recent years, there has been a massive proliferation of bark beetles affecting silver fir (*Abies alba* Miller) and Norway spruce (*Picea abies* Karsten) in the Alpine and Apennine areas, mostly due to large-scale logging, climate change, and windstorms (Kirkendall & Faccoli 2010; Salvadori *et al.* 2021; Bozzini *et al.* 2023).

In Italy, silver fir forests cover nearly 70,000 hectares (Gasparini & Papitto 2022), with a predominantly Alpine distribution (almost 80%). Structural data is lacking for approximately 65% of these forests, whereas the remaining portion is predominantly (90%) single-layered. There are numerous adverse factors affecting the *Abies* genus, including root rot, inadequate silvicultural practices, air pollution, and climate change (repeated droughts), which are compounded by the presence of phytophagous insects. Among these, bark beetles are particularly harmful, as their attacks can have severe consequences for the survival of silver fir forests (Faccoli 2000).

The fir engraver beetle, *Pityokteines curvidens* (Germar, 1823) (Curculionidae: Scolytinae), is one of the most common fir pests (Pennacchio *et al.* 2002a). Tree colonization by *P. curvidens* typically occurs in early spring (April) on thin bark of the upper trunk and large branches (Chararas 1962). Medium-sized adults (1.8–3.2 mm) infest stressed fir trees or stacks of non-debarked logs. Females bore

a transverse system of egg galleries, typically three to eight galleries about 6 cm long and 1.5–2 mm wide, arranged in a characteristic cross-brace pattern. Larval galleries, up to 7 cm long, are numerous, regular, and closely spaced, running perpendicular to egg galleries. *P. curvidens* may produce one or two generations per year depending on elevation and local climate. The species overwinters as adults in hibernation chambers excavated in the phloem of the middle-upper trunk and begins new breeding systems in the following spring (Chararas 1962).

Other bark beetles infesting silver fir in southern Europe include *P. spinidens* (Reitter, 1895), *P. vorontzowi* (Jakobson, 1895) and *Cryphalus piceae* (Ratzeburg, 1837), which are the most common species occurring in the Apennine regions where silver fir forests are dominant (Harring 1978).

In Italy Silver fir, a remnant of the last glacial period, has significant historical and phytogeographical value, and serves as an important genetic resource due to its differentiation. In central Italy, within the Molise region, fir is distributed in fragmented stands in the northern part of the region (Pallotta 1930), covering a total area of approximately 1200 hectares (Gasparini & Papitto 2022), which once formed a continuous forest stand.

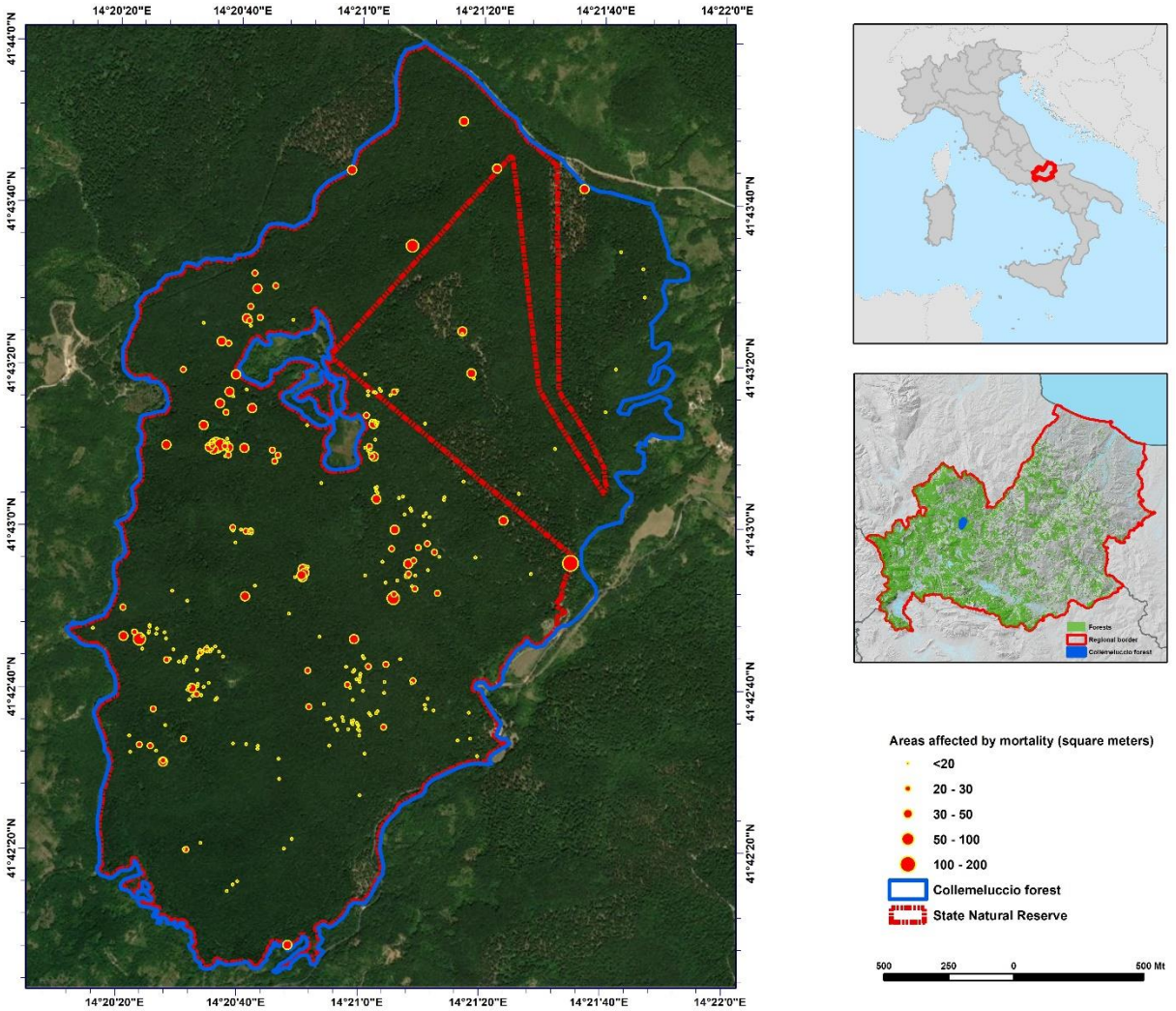

Figure 1. The mapped areas of the Collemeluccio forest affected by tree mortality.

One of the most important stands of *A. alba* in Molise is represented by the Collemeluccio Forest, which spans approximately 500 hectares (Figure 1) in the municipality of Pescolanciano, in the Isernia province (Molise Region, Central Italy). Approximately 347 hectares of this forest fall within the Collemeluccio-Montedimezzo UNESCO Man and Biosphere (MaB) Reserve (Abbate 1990). The site is under various levels of protection; since 1971, it has been designated as a nature reserve, and in 1977 it was declared a Biogenetic Reserve. Additionally, this forest is part of the Natura 2000 network

within the Special Protection Area (SPA) IT7221131 “Bosco di Collemeluccio” and the Special Area of Conservation (SAC) IT7212134 “Bosco di Collemeluccio-Selvapiana”. The habitat is typical of the hilly areas of the central-southern Apennines. The altitude ranges between 792 and 1,075 meters above sea level. Precipitation averages 900 mm per year, mostly concentrated in autumn. Average temperatures range from 4.6°C to 13.8°C , with an annual average of 8.4°C (Vizzarri *et al.* 2014).

Silver fir constitutes approximately 70% of the Collemeluccio forest, together with other less common species such as sessile oak (*Quercus petraea* (Matt.)), beech (*Fagus sylvatica* L.), hornbeam (*Carpinus betulus* L.), and field maple (*Acer campestre* L.) (Vizzarri *et al.* 2014). The silver fir component of the Collemeluccio forest is considered even-aged due to intensive forestry exploitation during World War I and World War II (Vizzarri *et al*. 2014). In the last years these stands became more susceptible to bark beetle attacks due to their advanced age and the climate change, which caused new stress conditions mainly related to prolonged drought (Jaime *et al*. 2024). The Management Plan for the SAC reports that, although it is considered to be in excellent condition, this silver fir forest is threatened by several pressures, including excessive forest uniformity, land instability, and poor regeneration (Vizzarri *et al.* 2014).

In July 2024, the first signs of silver fir decline (i.e. crown discoloration, death trees) were reported in the Collemeluccio Reserve. Following a preliminary inspection carried out in September 2024 throughout the Collemeluccio forest, the declining silver firs were found to be infested by the fir engraver beetle *Pityokteines curvidens*. The bark infestations were associated with crown discoloration, needles loss, branches drying and, in the most serious cases, death of the trees (Figure 2). The fir engraver beetle is a common species in mature fir forests suffering from drought or root pathogen infections (Pennacchio *et al.* 2002a). Although it is considered a secondary species (i.e., attacking only weakened or recently dead trees), *P. curvidens* is one of the most common bark beetle species in the silver fir forests, often associated with *P. vorontzowi* and *P. spinidens* (Lieutier *et al*. 2016).

An accurate survey was then conducted to investigate the cause of the forest mortality through direct debarking of decaying or dead trees in the most infested areas of the Reserve (see Figure 1). Subsequently, expedited mapping was carried out via 30/07/2023 Google Satellite high-resolution imagery (https://earth.google.com/), which enabled the identification and mapping of approximately 290 spots of decline, with affected surface areas ranging from 15 to 200 square meters.

P. curvidens (Figure 3) was recognized as the primary cause of fir mortality in these areas. This species is one of the most common fir pests in Europe (Pennacchio *et al.* 2002a; Pennacchio *et al.* 2002b). In Italy, *P. curvidens* is known to occur in Calabria, Molise, Piemonte, Emilia Romagna, Toscana, and Friuli Venezia Giulia (Faccoli 2000; Pennacchio *et al.* 2002b), following the distribution range of silver fir.

The infestations are currently primarily concentrated in the central part of the MaB Collemeluccio-Montedimezzo Reserve (Figure 1), which extends in a southeast–northwest direction, in areas with more open habitats, such as clearings, meadows, and the trail networks, and then progressively spreads inland (Figure 1-2). It is less widespread in the northeastern sector.

The first infestation of *P. curvidens* observed in the Collemeluccio forest dates back to Pallotta (1930), who noted that this silver fir forest was suffering some silvicultural practices—such as selective or strip cutting—which likely aroused an increase in bark beetle populations. Additionally, during the same period, the presence of *P. curvidens* was also reported in the silver fir forest of Selvapiana in Pescopennataro (IS) (Faccoli 2000), where the level of infestation was so high that it led to the full clear-cutting of the forest. After the first infestation recorded around 1930, no further reports of silver fir infestations have been documented for this area (Collemeluccio forest).

Recent studies conducted in fir forests of Vallombrosa forest (Tuscany) using 47 window flight traps located in *F. sylvatica* and *A. alba* pure and mixed stands activated with a blend of beer and wine, 33 specimens of *P. curvidens* were captured (Parisi *et al*. 2024).

Today, there is a new and significant spread of *P. curvidens* causing the death of many *A. alba* trees, particularly in the Collemeluccio forest. The infestation affects both the dominant and lower stand layers, with field survey revealing widespread mortality of isolated dominated firs, which are not visible in remote sensing images. Mapping of these areas would further increase the accuracy of the damage data shown in Figure 1.

Figure 2. *Abies alba* trees showing clear signs of decay in the Collemeluccio silver fir forest. Photos by F. Parisi.

Prolonged water stress weakens trees, facilitating infestations by bark beetles, which can then colonize the trees in large numbers. Infested firs exhibit reduced osmotic pressure, lower sugar levels, and changes in the terpene compounds released, with an excess of resin production (Chararas 1975). Managing insect infestations is difficult and mainly relies on preventive measures, such as phytosanitary

thinning to promptly remove materials that can be infested by beetles. Special attention should be given to standing dead trees damaged by climatic events or forestry operations, as well as to piles of debarked logs, which can become an infestation source (Tsankov 1994). If trees or trunks are already infested, debarking before adult emergence can significantly reduce the bark beetle population and limit damage to surrounding trees. It is therefore likely that the stress condition of the fir trees, and the subsequent *P. curvidens* infestation, are connected to the particularly hot and dry climate of the preceding years.

The infestation of *P. curvidens* in the *A. alba* forest at the Collemeluccio Reserve presents a significant ecological threat, particularly in the context of ongoing environmental changes (Lieutier *et al*. 2016). As climate change continues to exacerbate the vulnerability of forests, the importance of proactive forest management and pest control becomes increasingly crucial (Jaime *et al*. 2024). Effective bark beetle management involves maintaining healthy, site-adapted tree species and ensuring adequate spacing between host trees. However, sustaining tree health across large areas can be challenging or even impossible, particularly during extreme droughts or severe storms. Nevertheless, selecting appropriate tree species and thinning stands can reduce environmental stress and have proven successful in preventing bark beetle outbreaks. These strategies directly address the factors that contribute to outbreaks, making them the most effective prevention methods (e.g. Schowalter 2012).

Further investigations are necessary to determine the size of the bark beetle population and the effective distribution of the local infestations in the Collemeluccio Reserve. The main measure provided for by the Management Plan for the SAC reports the transformation from even-aged to uneven-aged high forests, through irregular cut (Vizzarri *et al*. 2014). By combining traditional forestry management practices with modern monitoring techniques (i.e., remote sensing), it may be possible to mitigate the impact of *P. curvidens* and other forest pests, thereby preserving both the biodiversity and genetic heritage of Italy's valuable *A. alba* forests.

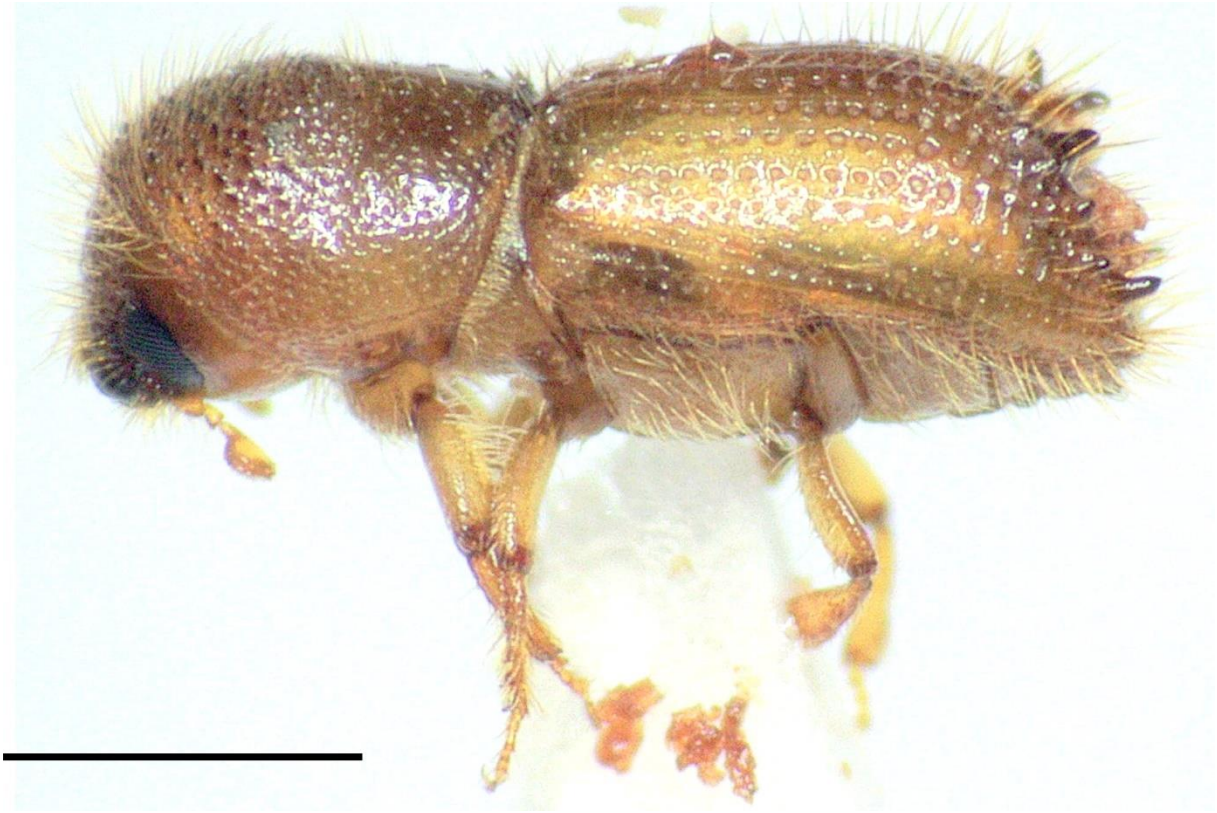

Figure 3. Lateral view of *Pityokteines curvidens* (Germar, 1823) found in the Collemeluccio silver fir forest. Scale bar = 1 mm. Photo by F. Parisi.

Acknowledgements

The authors thank the Reparto Carabinieri Biodiversità di Castel di Sangro for their availability and cooperation. Additionally, we are grateful to Prof. Paolo Di Martino, Dr. Cherubino Zarlenga, and Dr. Marco Montella for their collaboration and the information provided.

This study was supported by the following projects: PNRR, a project funded under the National Recovery and Resilience Plan (NRRP), Mission 4, Component 2, Investment 1.4—Call for tender No. 3138 of 16 December 2021, rectified by Decree n.3175 of 18 December 2021 of the Italian Ministry of University and Research funded by the European Union–NextGenerationEU; Project code CN_00000033, Concession Decree No. 1034 of 17 June 2022 adopted by the Italian Ministry of University and Research, CUP H73C22000300001/F83C22000730006, project title "National Biodiversity Future Center - NBFC".

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