EPPO Datasheet: *Polygraphus proximus*

Last updated: 2024-02-02

IDENTITY

Preferred name: *Polygraphus proximus*
Authority: Blandford
Taxonomic position: Animalia: Arthropoda: Hexapoda: Insecta: Coleoptera: Curculionidae: Scolytinae
Other scientific names: *Polygraphus abietis* Kurentsov, *Polygraphus horyurensis* Murayama, *Polygraphus laticollis* (Wood & Bright) Eggers, *Polygraphus magnus* Murayama, *Polygraphus miser* Blandford, *Polygraphus nigricans* Kurenzov, *Polygraphus oblongus* Blandford
Common names: Japanese silver-fir bark beetle, Sakhalin-fir bark beetle, four-eyed fir bark beetle
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EPPO Categorization: A2 list
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EU Categorization: Quarantine pest ((EU) 2019/2072 Annex II A)
EPPO Code: POLGPR



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Notes on taxonomy and nomenclature

The following synonyms have been used for *Polygraphus proximus* Blandford, 1894 (Coleoptera, Curculionidae: Scolytinae): *Polygraphus magnus* Murayama, 1956 (Wood, 1992), *P. laticollis* Eggers (Wood & Bright, 1992), *P. miser* Blandford, 1894, *P. nigricans* Kurentsov, 1948, *P. oblongus* Blandford, 1894 (Knizek, 2011). In addition, Krivolutskaya (1996) listed *P. abietis* Kurentsov, 1941 as a synonym of *P. proximus*. Mandelshtam (2013), based on the study of original description and type material, added *P. horyurensis* Murayama, 1937 to the list of synonyms of *P. proximus*.

HOSTS

Polygraphus proximus is a bark beetle primarily attacking firs (*Abies* spp.) and also infesting a number of other Pinaceae.

In its native range (Far East), *P. proximus* develops on native fir species: *Abies nephrolepis* (main host), *A. sachalinensis, A. holophylla, A. mariesii, A. firma, A. homolepis* (Niisima, 1909, 1910; Kôno & Tamanuki, 1939; Niijima, 1941; Kurentsov, 1941; Krivolutskaya, 1958, 1996; Nobuchi, 1966). In Japan, the beetle causes significant mortality of weakened stands of *Abies firma* (Tokuda *et al.*, 2008) and notably attacks stands of *A. veitchii* (Takagi *et al.*, 2018). In its native range, it was occasionally documented on *Picea jezoensis, Picea glehnii, Pinus densiflora, Pinus pumila, Pinus parviflora, Larix gmelinii, Larix kaempferi, Tsuga sieboldii* (Niijima, 1941; Nobuchi, 1966, 1979). In mixed conifer forests, *P. proximus* still prefers *Abies* spp. to other conifers (Niijima, 1941). However, the relationships between *P. proximus* and its host plants might be more complex than originally thought, as during field studies on the colonization of *P. proximus* on various *Abies* species conducted in Japan, a mismatch between host preference and colonization success has been observed. The colonization of *A. sachalinensis* was high despite the fact that it was the least preferred species, and the colonization of *A. firma* was low although it was the most highly preferred species (Takagi, 2023).

In its invaded range, in particular in Siberia, *P. proximus* infests a novel host, *A. sibirica* (Siberian fir), causing severe damage and tree mortality on a large scale (Kerchev, 2014a). *Abies* species belonging to the botanical sections Balsamea (which includes *A. sibirica* and the North American *A. balsamea*) and Grandis (North American *Abies* species) are highly preferred hosts, whereas fir species from the section Abies (which includes European fir species, such as *A. alba* and *A. nordmanniana*) are the least preferred among *Abies* species (Kerchev, 2012; Kerchev, 2014a).

In indoor experiments, *P. proximus* showed the ability to develop (i.e. complete one generation and provide fertile offspring) on *Picea obovata* (Siberian spruce), *Pinus sibirica* (Siberian pine), and *Larix sibirica* (Siberian larch) (Kerchev, 2012). In Siberia, *P. proximus* usually does not attack spruce and pine species, although, infestations of wind-broken spruces and pines (*P. sylvestris* and *P. sibirica*) have been recorded in very rare cases (e.g. on a storm damaged branch of *P. sylvestris*; Kerchev, 2014a).

In the European part of Russia, the beetle was found in plantings of *A. sibirica*, *A. balsamea* and *Picea* sp. in Moscow Oblast (Chilakhsaeva, 2008), and severe outbreaks have been observed in native stands of *A. sibirica* in other administrative regions (Dedyukhin & Titova, 2021; Subris, 2003; Semenova, 2023). In a botanical garden in Moscow, the beetle caused significant damage to North American fir species: *A. arizonica, A. balsamea, A. fraseri*, and the East Asian fir species, *A. veitchii* (Seraya *et al.*, 2014). In the same botanical garden, lower levels of infestation were recorded on *A. lasiocarpa, A. concolor, A. gracilis, A. nephrolepis, A. sachalinensis, A. sachalinensis* var. *mayriana*, whereas, *A. alba, A. excelsior, A. holophylla, A. homolepis, A. koreana, A. nordmanniana*, and *A. semenovii* trees were not infested (Seraya *et al.*, 2014).

Host list: *Abies balsamea, Abies concolor, Abies firma, Abies fraseri, Abies grandis, Abies holophylla, Abies homolepis, Abies koreana, Abies lasiocarpa, Abies mariesii, Abies nephrolepis, Abies sachalinensis var. mayriana, Abies sachalinensis, Abies sibirica, Abies veitchii, Larix gmelinii var. gmelinii, Larix gmelinii, Larix kaempferi, Picea glehnii, Picea jezoensis, Picea obovata, Pinus densiflora, Pinus koraiensis, Pinus parviflora, Pinus pumila, Pinus sibirica, Pinus sylvestris, Tsuga sieboldii*

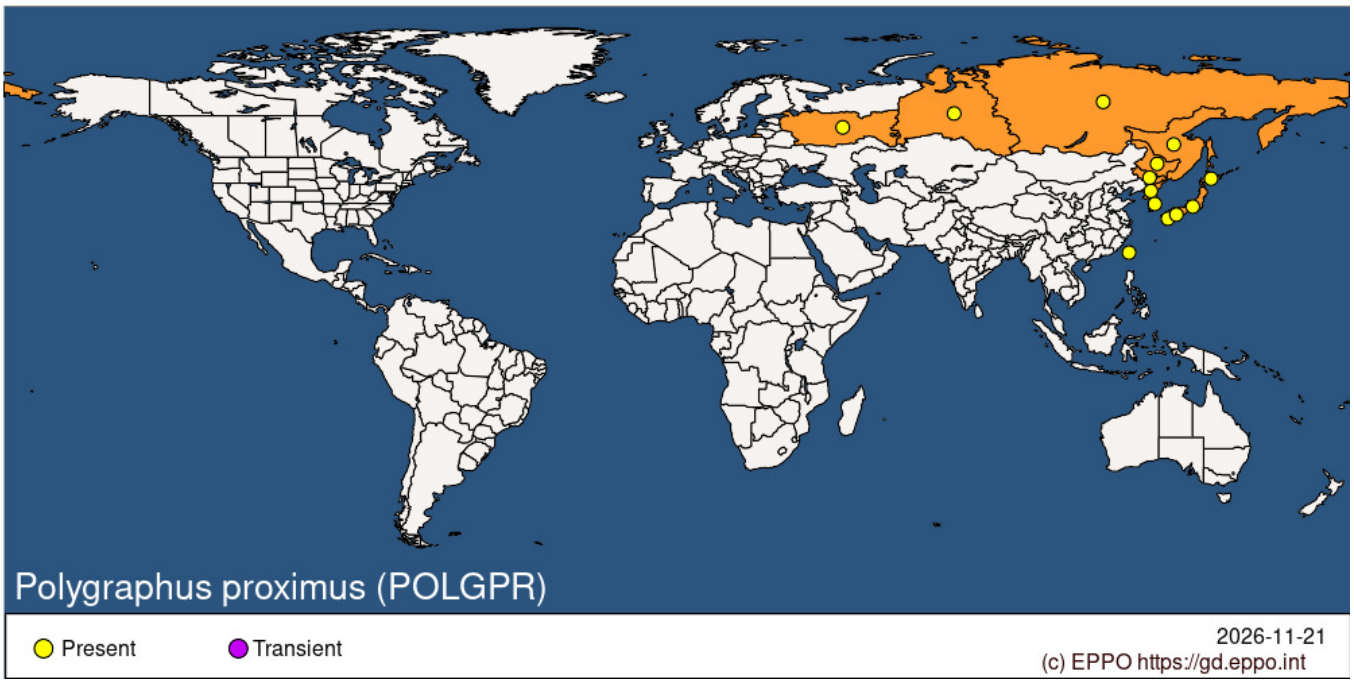
GEOGRAPHICAL DISTRIBUTION

Polygraphus proximus originates from the Far East (China (mostly northeastern part), Japan, Korean Peninsula, and the Russian Far East), where it is one of the most common and widespread bark beetles (Niisima, 1909, 1910; Niijima, 1941; Krivolutskaya, 1958; Knizek, 2011; Park, 2018). Its native range mainly stretches (approximately) between the latitudes 32°54’N and 48°41’N and the longitudes 127°50’E and 148°31’E. As an exception, Yushan (Taiwan) is the most southern record (Nobuchi, 1979).

In the Russian Far East, *P. proximus* is naturally present in Primorsky and Khbarovskiy Krais, Sakhalin and some of Kuril Islands. Elsewhere in Russia, *P. proximus* is an invasive species causing significant ecological and economical damage to the forest sector (Kerchev, 2014a), and affecting urban plantings (Seraya *et al.*, 2014). The beetle was first found outside its native range in Western Siberia, Kemerovo Oblast (54°56?N 87°14?E), in 2005 (Baranchikov *et al.* , 2011), where it was first erroneously identified as another bark beetle, *Xylechinus pilosus* (Baranchikov *et al.*, 2011). In Siberia, *P. proximus* has been recorded over a huge territory: from at least 51º33?N to 58º22? N and from west to east from 83º04?E to 94º44? E (Krivets *et al.*, 2015a, 2015b). During the last two decades, *P. proximus* was also reported in Eastern Siberia (Bystrov & Antonov, 2019), the Urals, and in a few regions of the European part of Russia (Krivets *et al.*, 2015a; Dedyukhin & Titova, 2021), including Moscow Oblast (55°37?N and 37°44’E) (Chilakhsaeva, 2008). In 2023, the species was detected in Northeastern Kazakhstan (50°45'N 83°01'E, 514 m a.s.l.) causing notable damage to *A. sibirica* in forest stands (Kirichenko *et al.*, 2023). However, this record was not confirmed by the NPPO of Kazakhstan in 2024.

Polygraphus proximus inhabits both plains and mountains. In Primorsky Krai (Russian Far East), the beetle was found from altitudes ranging from 700 m a.s.l. (Kerchev, 2014a) up to 1300 m a.s.l. (Kurentsov, 1941). In West Siberia (invaded range), it is found in the southern taiga and subtaiga of the West Siberian Plain at an altitude of 100 m a.s.l. The maximal altitudinal record is 1493 m a.s.l. (in Altai Republic), which is the limit of Siberian fir distribution in the mountain-taiga belt (Kerchev, 2014a).

In general, *P. proximus* lives in cool continental and moderate insular climates (including monsoon climate) and is associated with coniferous forests, mostly dark (fir-spruce) and mixed forests (with inclusion of fir, spruce and pines). In the native range, the beetle distribution coincides with the range of Far Eastern species of firs, in the invaded range (Siberia and the European part of Russia) with that of Siberian fir (*A. sibirica*).



EPPO Region: Russian Federation (Central Russia, Eastern Siberia, Far East, Western Siberia)
Asia: China (Heilongjiang, Jilin), Japan (Hokkaido, Honshu, Kyushu, Shikoku), Korea, Democratic People's Republic of, Korea, Republic of, Taiwan

BIOLOGY

Polygraphus proximus habitats include pure fir forests, poly-dominant fir-pine-spruce forests with an admixture of aspen and birch, low-mountain black forests (Krivets *et al.*, 2015a, 2015b). In its native range, beetles choose wind-fallen and wind-broken trees, cut logs as well as living trees weakened by abiotic (fire) and biotic (pathogens, phyllophagous insects) factors (Kurentsov, 1941; Nobuchi, 1966). In its invaded range, in addition to weakened and fallen trees, it attacks live and healthy stands of *A. sibirica* (Kerchev, 2014a). Outbreaks usually occur in forest monoculture or stands where fir predominates, but the pest can also attack isolated fir trees in mixed forests and urban plantings (Kerchev, 2014a; Seraya *et al.*, 2014).

P. proximus infests both trunk and thick branches (Kurentsov, 1941). It seems to prefer trees with rougher bark (Takei *et al.*, 2021).

In the Russian Far East and Western Siberia, *P. proximus* has two generations per year, the first developing from mid-May to mid-July, the second in August-September. In some cases, generations overlap (Kurentsov, 1941; Kerchev, 2014b). The adult beetles communicate using an aggregative pheromone, which is mainly produced by males (although females also seem to be able to produce it) (Viklund *et al.*, 2022), and species-specific acoustic signals produced by both sexes (Kerchev, 2020). The beetle is a vector of phytopathogenic fungi, mainly *Grosmannia aoshimae*, *Ophiostoma subalpinum* and *O. nikkoense* (Yamaoka *et al.*, 2004; Pashenova *et al.*, 2018). Fir logs infested by *G. aoshimae* are more attractive for colonization by *P. proximus* (Pashenova *et al.*, 2018).

Polygraphus proximus is a monogamous species (Kerchev, 2014b; Köbayashi & Takagi, 2020). The male makes an entry hole and bores a tunnel into the bark. Attracted by the pheromone (Kerchev, 2014b), a female penetrates into the tunnel through the entry hole for mating (Kerchev, 2014a, 2014b). The female lays eggs in distal parts of the galleries, and larvae then make perpendicular galleries. Mature larvae gnaw a pupal chamber in the sapwood (Kerchev, 2014b). After emergence, young beetles remain in the galleries for some time for feeding. During summer, all stages i.e. eggs, larvae, pupae, adults can be found in or under the bark or in the sapwood. After maturing, adult beetles make exit holes and fly to new host trees (Kurentsov, 1941; Kerchev, 2014b). The adult beetles that emerge in autumn overwinter in the galleries under the bark and exit from trees the next season (Kurentsov, 1941). Late instar larvae and pupae can also overwinter; the proportion of overwintering larvae and pupae vs. adult beetles is 1:3 (Kerchev, 2014b).

In galleries, the larvae, pupae and beetles can resist winter air temperatures down to –37.3° C, and even episodic temperature decrease down to –48.7° C (Kerchev, 2014b). In laboratory observations, at constant temperature (+22°C) and humidity (85%), one generation takes about 50 days; the flight peak occurs 5 days after the first beetles emerge (Kerchev, 2014a). Adults fly on sunny and calm (windless) days with air temperature above +15°C. However, windy and cloudy weather, as well as high precipitation can interrupt adult flight and, thus, extend the flight period (Krivolutskaya, 1958). During outbreaks in Western Siberia, 1.5 to 7.5 colonies of *P. proximus* per dm^2 were recorded within infested trees (Kerchev, 2014b).

In general, after emergence, adult beetles select trees within a radius of 50 m, although some can cover distances exceeding 100 m, to form new colonization sites (Kerchev & Torchkova, 2018). In Baikal region, over 7 years (from 2014 to 2021), the beetle range had expanded up to 95 km, with an expansion rate of 13-14 km/year (Kerchev *et al.*, 2023).

DETECTION AND IDENTIFICATION

Symptoms

The external signs indicating the presence of *P. proximus* in fir stands are as follows: pronounced resin flow on tree trunks of live trees, exit holes (round, about 2 mm in diameter) on trunks and large branches and the presence of fine pinkish-brown sawdust in the lower part of tree trunk and on the grass around the tree (Baranchikov *et al.*, 2011; Krivets *et al.*, 2015a, 2015b). Later on, attacked trees are easily recognized by the presence of red needles on some branches in the lower part of tree crown (or on all branches after 2-4 years of infestation) which may be accompanied by the simultaneous presence of dead trees in forest stand, with no needles and numerous exit holes on tree trunks (Krivets *et al.*, 2015b).

Early internal signs of presence are the attempts to colonize the tree: the entrance holes (approximately 2 mm in diameter) filled with resin; in some cases, bright orange necrotic spots (up to 10 mm in diameter) in phloem tissues caused by phytopathogenic fungi vectored by the beetles, in particular *Ophiostoma* sp.(Yamaoka *et al.*, 2004;Baranchikov *et al.*, 2011; Krivets *et al.*, 2015a). When colonization is successful, the internal signs of presence are characteristic galleries under the bark (usually double-armed mother galleries under the bark in phloem layer, located transversely on a standing trunk; at high densities, they are arranged randomly) (Kurentsov, 1941; Nobuchi, 1966; Kerchev, 2014a, 2014b). Triple- or four-armed mother galleries may also be found; they have a shape of radially diverging rays or star-like patterns (Kurentsov, 1941; Kerchev, 2014a, 2014b). The mother gallery system is usually 2-3 cm long, exceptionally 5-6 cm (Niijima, 1941).

Other characteristics signs are pupal chambers (oval depressions) in the sapwood, with the simultaneous presence of larvae, pupae and young, light brown small (around 3 mm long) beetles in the galleries under the bark or in the sapwood, or mature (black) beetles preparing to exit the damaged tree (Baranchikov *et al.*, 2011; Kerchev, 2014a).

Morphology

Egg

The eggs are white, broadly oval, and relatively large for bark beetles (about 0.8 mm in length) (Krivets *et al.* 2015b). In Western Siberia, mean fecundity is 45±15 eggs (Kerchev, 2014b). No specific characters of eggs are known which would allow identification of the species.

Larva

The larva is white, legless, with a well-defined head, slightly bent downwards. Larvae have three instars, which are identified based on the width of the head capsule: larvae of the 1^{st} instar are 0.38±0.07 mm, 2^{nd} – 0.53±0.07 mm, 3^{rd} – 0.68±0.08 mm (Krivets *et al.*, 2015b). No specific characters of larvae are known which would allow identification of the species.

Pupa

The pupa is spindle-shaped. Right after pupation, the pupa is translucent; on the 2nd–3rd day, it becomes milky white, on the 4th day, pupal chitin gets darker, including mandibles and legs. The pupation stage takes about 7 days. A mature pupa is yellowish-whitish with dark brown mandibles and eyes, and the wing primordia are smoky grey (Krivets *et al.*, 2015b). No specific characters of pupae are known allowing identifying the species.

Adult

Adult is up to 2.4–3.2 mm long (Park, 2018). The beetle is black with elytra gradually reddish towards apex; legs are dark red; tarsi and antennae are yellowish-red (Kuznetsov, 1941; Park, 2018). The forehead is flattened ventrally and convex dorsally, rather densely punctured; the male has two blunt, adjacent tubercles (Kurentsov, 1941), and the female has an even brush of reddish hairs. The eyes are divided into two parts (Krivolutskaya, 1996). The antennal flagellum is 6-segmented (if counted with pedicel) and the antennal club is bluntly pointed, large, twice as long as the flagellum. The abdomen is covered with long and dense light hairs directed backwards. The pronotum is wider at the base and tapering towards the anterior margin (Kurentsov, 1941). The elytra are short and wide, two-thirds as wide as long. The punctate grooves of the elytra are shallow and unclear. The entire surface of the elytra is covered with thick, slightly protruding greyish-yellow scales, the thorax and abdomen are covered with adjacent scales and hairs (Stark, 1952). The adult of *P. proximus* can easily be distinguished from related species living on firs in Europe (*P. poligraphus* , *P. subopacus*) by the shape of the antennal club, the 5-segmented antennal funicle (without pedicel) and vestiture on pronotum of fine, sparse hairs and elongate scales and larger body size (Stark, 1952).

Detection and inspection methods

In tree stands, visual inspection of tree trunks, branches, and examination of the bark and phloem tissues underneath the areas near entrance/exit holes are the main detection method (Krivets *et al.*, 2015b). This can be applied to live, dead, fallen trees, logs with bark and pallets (Krivets *et al.*, 2015b).
Aerial methods can be used to detect damaged trees in forest stands (i.e. trees showing certain amount of red needles, dying or dead trees). A new convolutional neural network model has been developed to determine forest spots damaged by *P. proximus* by using images of fir forests collected by unmanned aerial vehicles (Kerchev *et al.*, 2021).

These external features of adults are sufficient to identify the species without the need to dissect male genitalia (Krivets *et al.*, 2015b). Male genitalia are illustrated and characterized in Kirichenko *et al.* (2023). DNA barcoding (i.e. sequencing of the DNA barcoding fragment of the mitochondrial cytochrome oxidase subunit 1 (COI) gene of the mitochondrial DNA) can be used to reliably identify the species, especially when immature stages (egg, larva, pupa) are collected, or when adult remnants are found in galleries during the inspection. To-date, 53 specimens of *P. proximus* (49 from the Russian Far East and Siberia and 4 from Japan) have been sequenced, and their DNA barcodes are publicly available in BOLD System for comparison (Taxonomy browser, 2023). All sequences correspond to one BIN (BOLD:AAN5824), the species code used in BOLD System; the maximal intraspecies genetic divergence reaches 2.03%, which could be used as a threshold to distinguish *P. proximus* from the related species (Kirichenko N., pers. comm.).

PATHWAYS FOR MOVEMENT

Adult beetles can naturally spread by flight and anemochory (movement with wind currents) (Krivets *et al.*, 2015a; Kerchev *et al.*, 2023).

Over long distances, the main pathway of *P. proximus* is probably the transportation of timber still carrying its bark of the host plants (*Abies, Pinus, Picea, Larix, Tsuga*) from countries where the pest is present. Wood may contain all stages (eggs, larvae, pupae and adults) (Kerchev, 2014a). In Russia, long-distance movement of the pest (from the Far East to Siberia and to Moscow region) is suspected to be caused by accidental transportation by trains on the Trans-Siberian Railway (Baranchikov *et al.*, 2011; Krivets *et al.*, 2015a, 2015b; Kononov *et al.*, 2016), as railway carriages transport timber (especially conifer logs with bark) and often have open platforms with side supports made from conifer wood.

Packaging material made with conifer wood is another possible pathway. One interception of *P. proximus* imported from Japan in a pallet made from *Cryptomeria japonica* (Cupressaceae) was documented by the quarantine

inspection in New Zealand (Brockerhoff *et al.*, 2003). *C. japonica* is not known to be a host plant of *P. proximus* (Kerchev, 2014a). This finding may indicate a possible risk of introducing of *P. proximus* with wood packaging material produced from conifer species, which are currently not known as hosts.

Movements of wood chips, wood particles, and wood waste processed from host trees in countries where *P. proximus* is present can be also an important pathway, as such materials may contain all stages of the pest (EFSA, 2020).

Considering that *P. proximus* can colonize trees of any size (Krivets *et al.*, 2015b), the import of conifer plants for planting and bonsais from the regions infested by *P. proximus* may potentially be a pathway of the pest movement.

PEST SIGNIFICANCE

Economic impact

In its native range, *P. proximus* usually attacks weakened trees of *Abies* spp., but also has the ability to damage and kill visually healthy fir trees (Niijima, 1941; Nobuchi, 1966; Koizumi, 1977). In 2008 in Japan, on the southern island of Kyushu, the beetle caused significant mortality of *A. firma* stands weakened by the curculionid *Parendaeus abietinus* (Tokuda *et al.*, 2008). In Hokkaido (Japan), it colonized live trees of *A. sachalinensis*, causing mass tree decline in forest stands in the 1970s (Koizumi, 1977). During studies conducted in two sites in Honshu and Hokkaido (Takagi *et al.*, 2018),*P. proximus* caused up to 38 % and 60% mortality in *A. veitchii* stands, respectively. *P. proximus* can also influence forest structure. In Japanese subalpine/subarctic territories, its outbreaks result in tree decline predisposing damaged stands to fires and, thus, posing a threat to the regeneration of *A. veitchii* forests (Takagi *et al.*, 2018). Furthermore, in the Far East, *P. proximus* is associated with phytopathogenic fungi from the genus *Ophiostoma*, which can be responsible for tree mortality, thus, accelerating tree decline (Ohtaka *et al.*, 2006).

In its invaded range in Russia, *P. proximus* causes major tree mortality and attacks healthy *A. sibirica* trees, a new host that is highly susceptible to the pest (Baranchikov *et al.*, 2011; Krivets *et al.*, 2015a; Astrakhantseva *et al.*, 2023; Semenova, 2023). The pest colonizes *A. sibirica* trees of any age and attacks fir undergrowth with a diameter of 6 cm, leading to the decline of entire fir stands (Krivets *et al.*, 2015b). Considering that *P. proximus* is capable of destroying trees before they reach reproduction stage, it could threaten the existence of *A. sibirica* as a species (Krivets *et al.*, 2015b). In Krasnoyarsk krai (Central Siberia) by 2018, fir mortality associated with *P. proximus* alone occurred on a territory of 541 400 ha, with significant ecological and economic impacts (Pavlov *et al.*, 2020). In Irkutsk region (Eastern Siberia), where the pest was detected for the first time in 2017 (with an estimated arrival in this region in 2005–2006), the outbreaks covered an area of 1655 hectares by September 2022 (Kobzar *et al.*, 2023).

In the invaded range, *P. proximus* also acts as a vector of an obligate symbiotic fungus, *Grosmannia aoshimae* (Ascomycota: Ophiostomataceae). This fungus originates from the Far East and arrived in Siberia with the beetle. The spread of this fungus leads to rapid weakening of *A. sibirica* trees resulting in unprecedented tree mortality (Pashenova *et al.*, 2012, 2018; Astrakhantseva *et al.*, 2014). In Siberia, massive death of fir trees occurred approximately 3–5 years after the first pest outbreak, followed by the complete collapse of forest stands (Krivets *et al.*, 2015b). Furthermore, fir stands attacked by *P. proximus* are infected and weakened by phytopathogenic fungi *Armillaria mellea* s.l. and *Heterobasidion annosum* s.l., as well as *Neonectria fuckeliana*, concomitant pathogens occurring in wood lesions after *P. proximus* attacks (Pavlov *et al.*, 2020).

In Siberia, *P. proximus* is a major cause of pronounced changes in ecosystem structure (Krivets *et al.*, 2015b; Bisirova & Krivets, 2018). In damaged forests, the microclimate changes dramatically, and as it negatively affects fir reproduction (Shabalina *et al.*, 2017) and results in replacement of taiga by areas overgrown with weeds or by deciduous tree stands (Bisirova & Krivets, 2018). Massive fall of dead trees leads to the accumulation of huge debris stocks and subsequently to a significant misbalance in carbon flux in the ecosystems (Mukhortova *et al.*, 2020).

In its native range, the pest has minor economic importance; however, mass decline of previously healthy trees of the Far Eastern fir species over notable area has been reported in Japan (Koizumi, 1977; Takagi *et al.*, 2018).

In the invaded range in Russia, *P. proximus* is a major forest pest causing significant economic losses (Mel'nik *et al.*, 2018). Annually, 750 000 m^3 of fir forest dies in Russia, with economic losses of at least 150 million rubles per year (Gninenko & Klyukin, 2011). In Tomsk Oblast (Siberia), direct economic losses can amount to a minimum of 24

000 RUB per ha, with additional indirect losses of 25 000 RUB per ha (Mel'nik *et al.*, 2018). Thus, only in one Siberian region (Tomsk), where outbreaks in 2016 were covering a territory of about 1931 ha, the overall costs (i.e. direct and indirect losses) amounted to about 92.14 million RUB (Mel'nik *et al.*, 2018).

Control

Clear-cutting is considered to be effective to eliminate foci and prevent further spread of *P. proximus* (Koizumi, 1977; Krivets *et al.*, 2015b). Clear-cutting should be carried out when it is confirmed that firs trees are infested and have no chance of surviving, and that the beetles have not yet completed their development within the trees (Krivets *et al.*, 2015b). The threshold for clear-cutting is the presence of around 10% of dying/ dead trees in the tree stands (Krivets *et al.*, 2015b). If clear-cutting is done in summer, trees must be debarked no later than 3–5 days after felling, and the logging residues and bark disposed of (e.g. burned) to prevent any further spread (Krivets *et al.*, 2015b). In infested logs, *P. proximus* can be killed by submerging debarked logs in water for one month (Krivets *et al.*, 2015b; Efremenko *et al.*, 2020).

Trap trees can be placed in infested forest stands one month before *P. proximus* adult emergence to allow partial capture and elimination of the pest population (Krivets *et al.*, 2015b). Soon after infestation, trap trees should be debarked, treated with insecticides, or completely destroyed, otherwise they may serve a source of *P. proximus* and other pests.

Injections with systemic insecticides can be done on individual trees only in small areas, so this is mainly only suitable in urban plantings (Krivets *et al.*, 2015b). A combined approach using systemic insecticides, timely felling and removal of colonized trees was highly efficient to eliminate the outbreak of *P. proximus* in the N.V. Tsitsin Main Botanical Garden of the Russian Academy of Sciences (Moscow, Russia) (Seraya *et al.*, 2018).

Pheromone monitoring has not been yet developed. Only recently, the specific components of the *P. proximus* pheromone have been identified. Two male-specific compounds, (Z)?DMCHE and 3-methyl-2-buten-1-ol were shown to be effective in attracting males and females in the field (Viklund *et al.*, 2022). However, further studies are needed as (Z)?DMCHE also attracts the adults of *Polygraphus subopacus* (Viklund *et al.*, 2022).

So far, natural enemies and entomopathogens could not control *P. proximus* in Siberia (Kerchev, 2014a). Overall, 24 species of predatory insects have been documented in Western Siberia, with *Thanasimus femoralis, Nudobius lentus* (Coleoptera) and *Medetera penicillata* (Diptera) being the most abundant larval predators. The latter species moved to Siberia from the Russian Far East together with *P. proximus* and is currently found in most infested areas (Kerchev & Negrobov, 2012; Kerchev, 2014b). Other dipterans, such as *M. signaticornis*, *Lonchaea bukowskii* and *Xylophagus sachalinensis* may have the potential to decrease pest population densities in Siberia (Krivosheina *et al.*, 2018). The far Eastern fly species, *Medetera penicillata* (Diptera, Dolichopodidae), which also spread to Siberia with *P. proximus*, appears to be the most specialized and abundant predator in Siberia (Kerchev & Negrobov, 2012). A highly virulent indigenous strain of *Beauveria bassiana*, present in Siberia, is a promising biocontrol agent for *P. proximus*, as in experiments, it could cause 100% insect mortality within 7–11 days at temperatures from 16°C to 24°C (Pavlov *et al.*, 2020).

Phytosanitary risk

In the EPPO region, *Abies alba* (European fir) and *A. nordmanniana* (Nordmann fir) are present in native forest stands, but both belong to the botanical section Abies, which is the least preferable host section according to laboratory tests (Kerchev *et al.*, 2014a). Therefore, the risk of their infestation by the pest could be estimated to be low. However, bearing in mind the recently documented mismatch between preference and colonization success in *P. proximus* observed on Far Eastern firs (Tagaki, 2023), the pest's behaviour towards its hosts (including those it has not encountered yet in nature) can be unpredictable. Taking in to account that *P. proximus* is able to successfully develop on other conifers naturally distributed in Europe (spruces, pines, larches), the phytosanitary risk could be significant.

The risk of introducing the pest with imports of fir debarked and treated logs, as well as with sawn fir wood is low, as the insect develops under the bark and in sapwood. Nevertheless, the pest can be accidently transported in conifer wood packing material (e.g. pallets) from Asia, even in those produced from trees not known to be host of *P. proximus*

(e.g. *Cryptomeria* sp., Cupressaceae) (Brockerhoff *et al.* 2003), which can increase phytosanitary risk.

In a pest risk analysis (EPPO, 2020), it was concluded that *P. proximus* could present a serious threat to conifer plantations and forests in all part of the EPPO region where host plants are grown.

PHYTOSANITARY MEASURES

In the regions which are at risk (i.e. areas where conifers from the family Pinaceae are present, efforts should be made to detect the pest as early as possible. Surveys should be conducted in the ports of entry using pheromone traps with newly found pheromone compounds to detect the entry of the pest. Control measures, which are similar to those used for the related bark beetles, can also be applied in adjoining infested areas, especially during outbreaks, to limit the spread of *P. proximus*.

To prevent the pest introduction, import of plants for planting and bonsais from host plants from infested areas should be strictly regulated; wood, cut branches, chips, pellets and other woody plant material from host plants (Pinaceae) and other conifers (e.g. Cupressaceae) from the infested areas should be appropriately treated (wood should be debarked, fumigated etc.). Alternatively, such commodities should originate from the areas free from the pest. Recommendations on consignment inspections and phytosanitary measures have been provided by EPPO (EPPO, 2019 and 2020).

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