ABS ACTA BIOLOGICA SIBIRICA
A journal on the biodiversity of Siberia and the adjacent lands

Acta Biologica Sibirica 10: 1699–1710 (2024)
doi: 10.5281/zenodo.14468138
http://journal.asu.ru

RESEARCH ARTICLE

Experimental rearing of the small spruce bark beetle *Ips amitinus* (Eichhoff, 1872) (Coleoptera: Curculionidae, Scolytinae) on aboriginal Siberian coniferous species

Nikita A. Smirnov[1], Ivan A. Kerchev[1]

1 *Institute of Monitoring of Climatic and Ecological Systems of the Siberian Branch of the Russian Academy of Sciences (IMCES SB RAS)10/3 Akademichesky Ave., Tomsk, 634055, Russia*

Corresponding authors: Nikita A. Smirnov (niknov918@gmail.com); Ivan A. Kerchev (ivankerchev@gmail.com)

Academic editor: R. Yakovlev | Received 7 October 2024 | Accepted 2 December 2024 | Published 18 December 2024

http://zoobank.org/4CD76371-169A-4D29-B9E9-49DB5DF7C924

Citation: Smirnov NA, Kerchev IA (2024) Experimental rearing of the small spruce bark beetle *Ips amitinus* (Eichhoff, 1872) (Coleoptera: Curculionidae, Scolytinae) on aboriginal Siberian coniferous species. Acta Biologica Sibirica 10: 1699–1710. https://doi.org/10.5281/zenodo.14468138

Abstract

The possibility of development of the invasive European species *Ips amitinus* (Eichhoff, 1872) on various coniferous species of Siberia was analyzed under laboratory conditions. The first experiment was carried out on fresh sections of the trunks of *Abies sibirica* Ledeb., *Picea obovata* Ledeb., *Larix sibirica* Ledeb., and *Pinus sylvestris* L., with the possibility for beetles to choose one of the four proposed tree species. The second experiment was conducted on the same tree species, but without the option for the beetles to choose the species for food. The third experiment consisted in breeding *I. amitinus* on *Pinus pumila* (Pall.) Regel. In the first two experiments on *P. sylvestris*, one generation of beetles developed successfully. It was found that *P. sylvestris* is the most favorable for the settlement and development of *I. amitinus* in the West Siberian invasion region followed by *P. sibirica*. On Siberian fir, Siberian spruce and Siberian larch, bark beetles died in galleries without forming nests. In the third experiment, successful beetle colonization of the branches was observed. In all the experiments, the demographic indicators of the pest were determined (settlement density, the number of parental beetles, the number of emerged beetles, offspring/parent ratio per unit area). These indicators were compared with those obtained on *P. sibirica*. A high probability of further expansion of the small spruce bark beetle both westward and eastward has been established.

Keywords
Ips amitinus, new trophic links, *Pinus sibirica*, Western Siberia

Introduction

Bark beetles (Coleoptera: Curculionidae: Scolytinae) are among the most important insect groups with regard to the health and sustainability of forest ecosystems worldwide (Raffa et al. 2015). The spread of invasive bark beetle species and their outbreaks can affect the carbon balance, thereby increasing the risk of forest transitioning from carbon sinks to carbon sources (Berryman 1988; Kurz et al. 2008).

The small spruce bark beetle *Ips amitinus* (Eichhoff, 1872) is widely distributed in many European countries (Mandelshtam et al. 2020). In recent decades, the species has been observed to expand its range to North European countries (Voolma 2004; Økland et al. 2019). In Russia, the small spruce bark beetle has been recorded in western, northwestern and northern regions of the European part of the country: Pskov, Novgorod, Murmansk and Arkhangelsk regions, and the Republic of Karelia (Voolma et al. 2004; Scherbakov et al. 2013; Mandelshtam et al. 2020). In its primary area, the bark beetle feeds on *Picea abies* (L.) H. Karst., *Pinus cembra* L. (Stauffer and Zuber 1998), and *Pinus mugo* Turr (Pfeffer 1995). The species has been observed occasionally feeding on *Abies alba* Mill. and *Larix decidua* Mill. (Pavlovsky 1955; Witrylak 2008).

Adults of *I. amitinus* overwinter in the inner bark or in forest litter. During spring dispersal, the species can fly up to 10 km to find new host trees (Forsse 1989). *Ips amitinus* commonly attacks the upper trunk of felled or weakened trees (Jeger et al. 2017). Once inside the host tree bark, male bark beetles begin producing aggregation pheromones (Francke et al. 1980) that attract conspecifics of both sexes. Bark beetle families are harem-polygynous, with one to seven females per male. Females bore a nuptial chamber in the phloem where mating occurs, and galleries are then initiated. The galleries are star-shaped and diverge radially, parallel to the fibers (Mandelshtam 1999). Each female lays about 75 eggs (Kerchev et al. 2020).

The distribution of insects along elevational gradients in the middle mountains ranges from 1400 m a.s.l. in France (Chararas 1962) to 1270 m a.s.l. in Slovenia (Jurc and Bojović 2004; Holusa et al. 2012). At altitudes below 600 m a.s.l., favorable weather conditions initiate sister generation formation, which leads to a highly confused phenology of the species (Holuša et al. 2012; Jeger et al. 2017).

In Western Siberia, the first confirmed finding of *I. amitinus* was recorded in 2019. The species was identified through a combination of morphological characters and molecular genetic analysis (Kerchev et al. 2019). In dark coniferous plantations in Tomsk, Kemerovo and Novosibirsk regions, there was a rapidly increasing bark beetle outbreak. *Pinus sibirica* Du Tour became a new object of bark beetle colonization (Kerchev et al. 2021). In collection plantings of introduced conifers at the "Kedr" station, the small spruce bark beetle successfully colonized *Picea obo-*

vata Ledeb. and *P. koraiensis* Nakai (Kerchev and Krivets 2021). This alien beetle was increasingly aggressive in the secondary area, resulting in rapid drying up of vast expanses of *P. sibirica* within a few years (Kerchev et al. 2022). In 2020, the area of extensive outbreaks in the West Siberian region reached 2440 ha (Kerchev et al. 2021).

Symbiotic relationships with ophiostomatoid fungi have been recorded for *I. amitinus*, which impaired the growth of trees in both primary and secondary areas (Kirisits 2004; Repe et al. 2013; Jeger et al. 2017; Pashenova et al. 2022).

In light of the rapid eastward expansion of the small spruce beetle (Kerchev et al. 2021), it is crucial to determine the potential host plants that may be encountered in the new range during its further expansion.

Potential beetle colonization of *P. koraiensis* poses a significant threat to the sustainability of Far Eastern forests. The Korean and Siberian pine ranges are geographically distant, and in addition to the railroad as a potential corridor for beetle invasion, the two areas are connected via a natural bridge formed by *Pinus pumila* (Pall.) Regel. range. The ability of the small spruce bark beetle to develop on *P. pumila* may facilitate its further eastward expansion.

The aim of the study was to identify plants susceptible to attacks of the small spruce bark beetle in the invasion region and to assess the potential of its further expansion.

Materials and methods

Three experiments were conducted to investigate aboriginal Siberian coniferous species. The first and second experiments were designed to identify potential host plants in the West Siberian invasion region, where active outbreak foci of the small spruce bark beetle are located. The third experiment was conducted to assess the potential for natural advancement of the bark beetle through the crossing ranges of *P. sibirica*, *P. pumila*, and *P. koraiensis* (Kerchev et al. 2021).

In the experiments, we employed the method of experimental rearing of bark and wood boring beetles on tree trunk sections, similar to the method previously used for another alien bark beetle species, *Polygraphus proximus* Blandford, 1894 (Kerchev 2012).

The first experiment was conducted on trunk sections of *Abies sibirica* Ledeb., *Larix sibirica* Ledeb. and *Pinus sylvestris* L., with the option for the beetles to choose the species for colonization. The experiment employed 250 first-generation beetles collected in the Siberian pine forest in the vicinity of the Luchanovo settlement (56°20'25.6"N, 85°2'37.8"E) in the inner bark of the windfall tree *P. sibirica*. The sections of coniferous trees for testing were also taken from this area. The experiments were conducted in five replicates using four sections (one of each species per replicate). Fifty beetles were placed into 5-liter plastic containers with the sections.

Similar to the first experiment, the second experiment was conducted on trunk sections, but without the option for the beetles to choose the tree species. The experiment employed 120 second-generation beetles. The coniferous species sections and bark beetles were collected in the same forest stand. In the experiment, three sections of each of the tree species with 30 beetles were placed in each of the four containers.

The settlements of *I. amitinus* on *P. sylvestris* from the first and second experiments were compared with sections *P. sibirica* naturally colonized by beetles in stand, which were used as a positive control. The section diameter for *P. sylvestris* ranged from 4.4 to 5.3 cm and that for *P. sibirica* spanned from 4.7 to 5.7 cm. The lateral surface area of the sections in the bark was 2.4 dm2.

The third experiment was conducted on sections of *P. pumila* versus *P. sibirica*. *P. pumila* sections were sampled from the Republic of Buryatia, the northern slope of Khamar-Daban, in the area of the Bolshoi Mamai River. The experiment employed 300 first-generation beetles collected in the Siberian pine forest in the vicinity of the Aksyonovo village (56°19'20"N, 85°7'57"E) in the inner bark of windfall branches of *P. sibirica*. Uncolonized branches of Siberian pine were collected in the same forest stand. The experiment was conducted in three variants, with 100 adults of the small spruce bark beetle each. The first experimental variant was conducted on five *P. pumila* sections, the second experimental variant employed five *P. sibirica* sections, and the third experimental variant was performed on three *P. pumila* and *P. sibirica* sections each. The section diameter was 2.9–4.14 cm for *P. pumila* and 3.03–4.68 cm for *P. sibirica*.

In all the three experiments, beetles were not separated by sex, the male to female ratio in the experiments was unknown. The temperature conditions of the experiments varied between +22°C and +25°C. Containers were covered with silk bolting cloth to prevent insect escape and section rotting. The evidence of bark beetle infestation was observed in the form of emergence of entry holes and the presence of boring dust at the bottom of the container. The criterion for successful colonization was the formation of nests in the inner bark. The containers with beetles were examined once every 2–3 days.

After the experiments were completed (emergence of young beetles), the section bark was dissected to count larvae, pupae and adults of *I. amitinus*. The main demographic indicators of the small spruce bark beetle (settlement density, the number of parental beetles, the number of emerged beetles, offspring/parent ratio per unit area) were determined using methodological recommendations for monitoring, accounting, and forecasting of mass reproduction of stem pests and forest sanitary condition (Methodological Recommendations 2006).

The data were subjected to descriptive statistical analysis using Microsoft Excel 2016, and the results were presented as median values with limits of variation (minimum and maximum values). The non-parametric Mann-Whitney U test (Statistica 12, $p \leq 0.05$) was employed to compare demographic indicators of the small spruce bark beetle.

Results and discussion

In the first experiment, the active phase of bark beetle settlement on sections was observed during the first 10–12 days. On spruce, fir and larch, the signs of infestation were typically found in the area of a cut or bark damage. On *Pinus sylvestris*, no clear confinement of the areas of entry holes to the areas of bark damage was recorded.

Boring of beetles into sections was observed on day 2. After 30 days, the emergence of young beetles was recorded. Successful colonization was observed only on *P. sylvestris*. On other species, feeding tunnels were observed up to 6 cm long, with beetle cadavers in the tunnels.

Numerous adults were detected in the inner bark of *P. sylvestris*, with some of them found in the pupal chambers. The color of the chitinous exoskeletons varied from almost white in recently emerged beetles to dark brown.

Settlement density on *P. sylvestris* was significantly ($U=0$; $p=0.012$) higher than that on *P. sibirica* (Fig. 1). This difference in indicators was likely due to the ability of the bark beetle to establish a more dispersed settlement in natural conditions, thereby minimizing intraspecific competition. The adverse effect of the competition can be observed through the comparison of offspring/parent ratios.

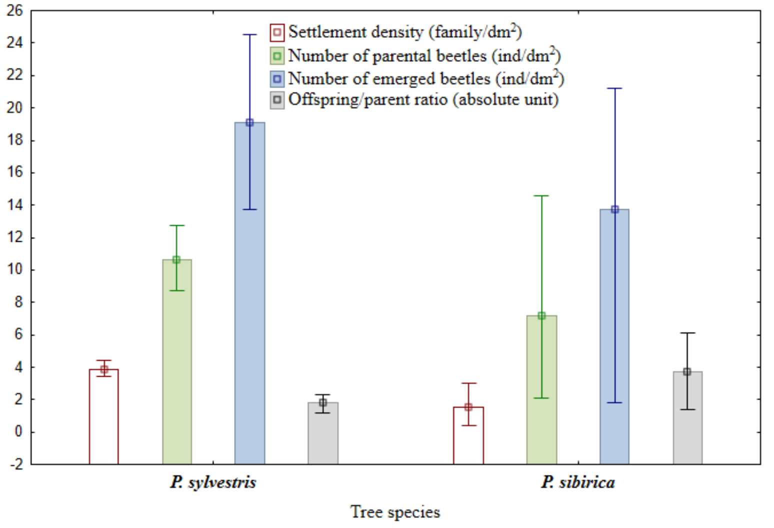

Figure 1. Demographic indicators of the small spruce bark beetle on *P. sylvestris* and *P. sibirica*, experiment 1.

In the second experiment, without the option for the bark beetles to choose the species as a food source, entry holes were observed on sections from all the containers. During the first 20 days, the amount of boring dust was found to increase; after that, new portions of boring dust were observed only for *P. sylvestris*. After 40 days, the bark was removed from the sections. Similar to the first experiment, successful colonization was recorded only for *P. sylvestris* (Fig. 1). Bark beetle larvae and pupae were found in the inner bark; 19 % of the young insects did not complete their development. Feeding tunnels on other tree species did not exceed 5 cm.

The results of this experiment showed no statistically significant differences in the demographic indicators of the small spruce bark beetle settlement on the studied tree species (Fig. 2).

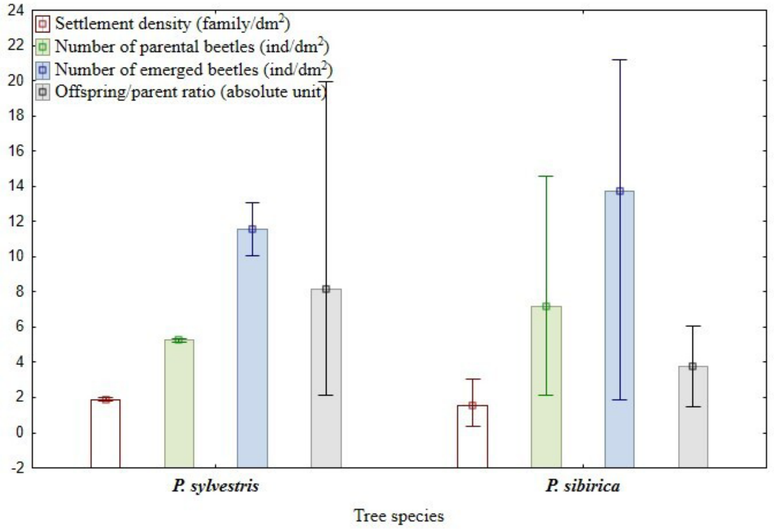

Figure 2. Demographic indicators of the small spruce bark beetle on *P. sylvestris* and *P. sibirica*, experiment 2.

In the third experiment, boring was recorded starting from the second day of observation. The emergence of the offspring from the sections was observed on days 30–35. Successful colonization and feeding tunnels were observed in all the experimental variants.

Of the two containers with *P. sibirica*, three sections showed no signs of boring. On *Pinus pumila*, the percentage of beetles without nests was 42%, on *P. sibirica*, it attained 43%, and in the container with different sections, it was 10%. All the young insects successfully transformed into imago after 40 days.

The results showed that under the same conditions the small spruce bark beetle preferred *P. pumila*. It was evidenced by a significant ($U = 12.5$; $p = 0.046$) difference in settlement density (Fig. 3).

To date, in the forests of Western Siberia, the small spruce bark beetle is abundant exclusively on *P. sibirica* (Kerchev et al. 2019). However, a high population size of the bark beetle and the absence of *P. sibirica* in the stand, the main source of food in the region, can lead to its attacks on *P. sylvestris*.

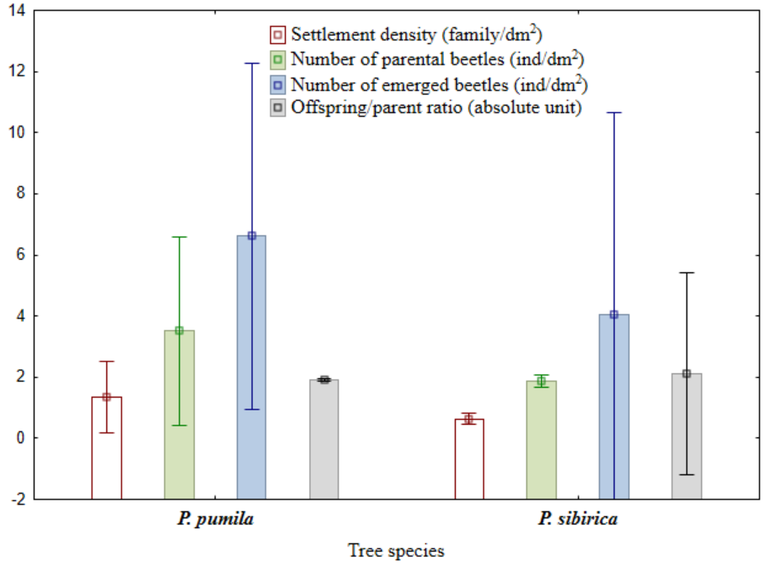

Figure 3. Demographic indicators of the small spruce bark beetle on *P. pumila* and *P. sibirica*.

The ability of the small spruce bark beetle to bore into and form galleries in trees of the genus *Abies* and *Larix* (Witrylak 2008) was confirmed neither in the experiment nor in natural stands of Western Siberia. It is notable that the small spruce bark beetle was not identified in the experiments conducted with *P. obovata*. Yet, isolated cases of bark beetle colonization and successful development on *P. obovata* were recorded in stands of the Tomsk region (Kerchev et al. 2019).

In field studies of the small spruce bark beetle in its primary area, *P. abies* was recorded as a preferred host tree more often than *P. sylvestris* (Annila and Nuorteva 1976; Witrylak 2008; Grodzki 2009; Holuša et al. 2012; Mazur and Kuźmiński 2013). Recent observations (Cocos et al. 2023) indicate that the occurrence and settlement density of the small spruce bark beetle in both field and experimental studies are higher on *P. abies* compared to *P. sylvestris*.

In its primary area, *I. amitinus*, together with *I. typographus* (Linnaeus, 1758) and *Pityogenes chalcographus* (Linnaeus, 1760), is a consort of *P. abies*, the main conifer species of subalpine and montane forests in Europe (Mazur et al. 2006). *Ips typographus* kills living trees by colonizing thick and middle bark in the butt-log and middle portions of the trunk. The small spruce bark beetle attacks the upper portion of the dying tree and colonizes the zone from the transitional to thin bark, where it sometimes enters into interspecific competition with *P. chalcographus*. In European spruce forests, *I. amitinus* shares ecological niches with more aggressive *I. typographus*, enabling it to maintain a stable population by exploiting the food supply made available by *I. typographus* outbreaks. The absence of *I. amitinus* outbreaks suggests that it does not typically feed on this coniferous species, which may be a limiting factor for the small spruce bark beetle in the primary area.

In the Siberian region of invasion, *I. amitinus* forms outbreak foci and kills *P. sibirica* stands, but it virtually does not develop on other conifer species under natural conditions. The experiments performed in this study showed that the small spruce bark beetle rarely attacks aboriginal Siberian coniferous species *Abies*, *Picea* and *Larix*. This is likely due to the active defense mechanisms and some repellent properties of trees of these genera that hinder the alien pest colonization.

The third experiment showed that the small spruce bark beetle can form nests and develop successfully on *P. pumila*. This means that the species can develop on all the three five-needle pine species growing in Russia. The possibility of further independent expansion of the small spruce bark beetle both westwards, within the range of *P. sibirica*, and eastwards, in the ranges of *P. pumila* and *P. koraiensis*, is very high.

Monitoring of the invasion of *P. proximus*, which occupied almost the entire range of *A. sibirica* within about 15 years after its first record (Kerchev et al. 2023), suggests that a similar scenario may be anticipated for the small spruce bark beetle.

The increased number of *I. amitinus* and its outbreak foci on *P. sibirica* in the vicinity of the Trans-Siberian Railway may facilitate its rapid eastward advancement.

Conclusion

1. Among the studied aboriginal Siberian coniferous species of Western Siberia, the small spruce bark beetle prefers feeding on *P. sylvestris* followed by *P. sibirica*.

2. Despite the lack of successful settlement observed in the experimental rearing of the small spruce bark beetle on coniferous trees of the genera *Abies*, *Picea* and *Larix*, the possibility of bark beetle colonization of logging residues and windfalls of these tree species cannot be completely excluded.

3. The demonstrated possibility of *I. amitinus* colonization of *P. pumila* indicates the potential for its successful expansion within the range of five-needle pine species.

4. It is crucial to monitor the expansion of the small spruce bark beetle and to study the mechanisms of suppression of the protective functions of *P. sylvestris* caused by attacks of the alien bark beetle and its symbionts, as well as the factors that ensure its successful colonization of other potential host species.

Acknowledgement

The study was supported by the Ministry of Science and Higher Education of the Russian Federation project No. FWRG-2022-0001.

References

Berryman AA (1988) Dynamics of Forest Insect Populations: Patterns, Causes, Implications. Plenum, New York, 603 pp.

Cocos D, Klapwijk MJ, Schroeder M (2023) Tree species preference and impact on native species community by the bark beetle *Ips amitinus* in a recently invaded region. In: Jactel H, Orazio C, Robinet C, Douma JC, Santini A, Battisti A, Branco M, Seehausen L, Kenis M (Eds) Conceptual and technical innovations to better manage invasions of alien pests and pathogens in forests. NeoBiota 84: 349–367. https://doi.org/10.3897/neobiota.84.86586

Dedyukhin SV, Titova VV (2021) Detection of the four-eyed bark beetle (*Polygraphus proximus* Blandford, 1894) (Coleoptera: Curculionidae, Scolytinae) in Udmurtia. Russian Journal of Biological Invasions 14(2): 32–39. https://doi.org/10.35885/1996-1499-2021-14-2-32-39 [In Russian]

Dominik J (2003) Research on damage of exotic coniferous species caused by indigenous insects – supplementary results. Sylwan 10: 25–28.

EPPO/CABI (1997) Quarantine Pests for Europe. In: Smith IM, McNamara DG, Scott PR, Holderness M, Burger B (Eds.) Data sheets on quarantine pests for the European Union and for the European and Mediterranean Plant Protection Organization. Second Edition. CAB International & European and Mediterranean Plant Protection Organization (EPPO), Wallingford, UK, 1425 pp.

Forsse E (1989) Migration in bark beetles with special reference to the spruce bark beetle *Ips typographus*. PhD thesis, Sveriges Lantbruksuniversitet, Uppsala.

Francke W, Sauerwein P, Vite JP, Klimetzek D (1980) The pheromone bouquet of *Ips amitinus*. Naturwissenschaften 67: 147.

Holuša J, Lukášová K, Grodzki W, Kula E, Matoušek P (2012) Is *Ips amitinus* (Coleoptera: Curculionidae) Abundant in Wide Range of Altitudes? Acta Zoologica Bulgarica 64 (3): 219–228.

Jeger M, Bragard C, Caffier D, Candresse T, Chatzivassiliou E, Dehnen-Schmutz K, Gilioli G, Jaques Miret JA, MacLeod A, Navajas Navarro M, Niere B, Parnell S, Potting R, Rafoss T, Rossi V, Urek G, Van Bruggen A, Van der Werf W, West J, Winter S, Kertesz V, Aukhojee M, Gregoire J (2017) Pest categorisation of *Ips amitinus*. EFSA Journal 15(10): 5038.

Kataev OA, Popovichev BG (2011) Forest pathology examinations for the study of stem pests in coniferous stands: textbook. SPb LTA, St. Petersburg, 72 pp. [In Russian]

Kerchev IA (2012) An experimental study of the possibility of the emergence of new trophic connections of the four-eyed bark beetle *Polygraphus proximus* Blandf. (Coleoptera: Curculionidae, Scolytinae) in Western Siberia. Bulletin of Tomsk State University. Biology 3(19): 169–177. [In Russian]

Kerchev I, Bykov R, Ilinsky Yu (2023) Expansion of the secondary range of *Polygraphus proximus* Blandford (Coleoptera; Curculionidae, Scolytinae): invasion of Khamar-Daban mountains (Republic of Buryatia). Acta Biologica Sibirica 9: 1–11. https://doi.org/10.5281/zenodo.7679805

Kerchev IA., Krivets SA (2021) An attack of *Ips amitinus* (Coleoptera: Curculionidae: Scolytinae) on arboretum in West Siberia: New host of invasive bark beetle among exotic conifers. Journal of Asia-Pacific Entomology 24(2): 148–152. https://doi.org/10.1016/j.aspen.2021.03.003

Kerchev IA, Krivets SA, Bisirova EM, Smirnov NA (2022) Distribution of the Small Spruce Bark Beetle *Ips amitinus* (Eichhoff, 1872) in Western Siberia. Russian Journal of Biological Invasions 13(1): 58–63. https://doi.org/10.1134/S2075111722010076

Kerchev IA, Krivets SA, Skorokhodov SN, Smirnov NA (2019) Small spruce bark beetle *Ips amitinus* – a new factor in the degradation of near-village stone pine forests in Western Siberia. In: Kabanov MV (Ed.) The Thirteenth Siberian Meeting and the School of young scientists on climate and environmental monitoring, Tomsk (Russia) (October 15–19, 2019). Agraf-Press, Tomsk, 188–189. [In Russian]

Kerchev IA, Krivets SA, Smirnov NA (2020) Analysis of population characteristics of the small spruce bark beetle *Ips amitinus* (Coleoptera: Curculionidae, Scolytinae) in the areas of invasion in Western Siberia. In: Musolin DL, Kirichenko NI, Selikhovkin AV (Eds) Dendrobiont invertebrates and fungi and their role in forest ecosystems. XI Readings in memory of O.A. Kataev. (November 24–27, 2020). St. Petersburg State Forestry Engineering University named after S.M. Kirov, St. Petersburg, 170–171. [In Russian]

Krivets SA, Kerchev IA (2011) Four-eyed bark beetle – a new dangerous pest of coniferous forests of the Tomsk region. Geo-Siberia 3(2): 219–223. [In Russian]

Krivets SA, Kerchev IA, Mandelstam MYu, Ilinsky YuYu (2019) Small spruce bark beetle *Ips amitinus* (Eichhoff, 1872) (Coleoptera, curculionidae: Scolytinae) – a new alien species in Western Siberia. Entomological Review 98(3): 592–599. https://doi.org/10.1134/S0367144519030092 [In Russian]

Kirisits T (2004) Fungal associates of European bark beetles with special emphasis on the ophiostomatoid fungi. In: Lieutier F, Day KR, Battisti A, Gregoire JC, Evans HF (Eds) Bark and wood boring insects in living trees in Europe, a synthesis. Springer, Netherlands, 181–236.

Knížek M, Trýzna M (2002) Kůrovci na borovici vejmutovce v Národním parku České Švýcarsko. Zpravodaj Ochrany Lesa 8: 54–55.

Kula E, Kajfosz R, Polívka J (2013) Attractiveness of *Picea pungens* to the bark beetle species *Ips amitinus* (Eichh.) and *Pityogenes chalcographus* (L.). Journal of forest science 59(12): 493–502. https://doi.org/10.17221/70/2013-JFS

Kurz WA, Dymond CC, Stinson G, Rampley GJ, Neilson ET, Carroll AL, Safranyik L (2008) Mountain pine beetle and forest carbon feedback to climate change. Nature 452: 987–990. https://doi.org/10.1038/nature06777

Lindgren BS, Raffa KF (2013) Evolution of tree killing in bark beetles (Coleoptera: Curculionidae): trade-offs between the maddening crowds and a sticky situation. The Canadian Entomologist 145: 471–495. http://dx.doi.org/10.4039/tce.2013.27

Lukasova K, Holusa J, Turcani M (2013) Pathogens of *Ips amitinus*: new species and comparison with *Ips typographus*. Journal of Applied Entomology 137: 188–196. https://doi.org/10.1111/jen.12000

Mandelshtam MYu (1999) Current status of *Ips amitinus* Eichh. (Coleoptera, Scolytidae) in North-West Russia. Entomologica Fennica 10: 29–34.

Mandelshtam MYu, Musolin DL (2016) The Ongoing Range Expansion of the Small Spruce Bark Beetle *Ips amitinus* (Eichhoff, 1872) (Coleoptera: Curculionidae: Scolytinae) in the Northwest and North of Russia. In: Baranchikov YN (Ed.) Monitoring and Biological Control Methods for Woody Plant Pests and Pathogens: from Theory to Practice. Institute of Forest, Krasnoyarsk, 129–130. [In Russian]

Mandelshtam MYu, Musolin DL, Økland B, Schroeder D. Flø M, Zach P, Cocos D, Martikainen P, Siitonen J, Neuvonen S, Vakula J, Nikolov C, Lindelöw Å, Voolma K, Krivets SA, Kerchev IA (2020) Range expansion of the small spruce bark beetle *Ips amitinus* (Coleoptera: Curculionidae, Scolytinae) in Northern Europe and Western Siberia. Dendrobiontic invertebrates and fungi and their role in forest ecosystems. St. Petersburg, 208–209.

Mazur A, Łabedzki A, Raj A (2006) Observations of phenology and frequencing of bark beetle (*Ips typographus* L.) and its accompanying species in the uppermost subalpine spruce forest zone environment in the Karkonoski National Park. In: Kolk A (Ed.) Insect outbreaks in managed and unmanaged forests. Forest Research Institute, Warszawa, 29–45.

Methodological Recommendations for Monitoring, Accounting and Forecasting of Mass Reproduction of Stem Pests and the Sanitary Condition of Forests (Ministry of Natural Resources and Environment of the Russian Federation (2006) Federal Forestry Agency; Russian Research Institute for Silviculture and Mechanization of Forestry (VNNIILM), Pushkino, 108 pp.

Økland B, Schroeder M, Zach P, Cocos D, Martkainen P, Siitonen Ju, Mandelshtam MYu, Musolin DL, Neuvonen S, Vakula J, Nikolov Ch, Lindelòw A, Voolma K (2019) Range expansion of the small bark beetle *Ips amitinus*: a newcomer in Northern Europe. Agricultural and Forest Entomology 21(3): 286–298. https://doi.org/10.1111/afe.12331

Pashenova NV, Kabilov MR, Kerchev IA (2022) Ophiostome fungi carried by the small spruce bark beetle in the Tomsk region. In: Problems of forest phytopathology and mycology. XI International Conference, Petrozavodsk (Russia), October 10-14, 2022. Karelian Scientific Center of the Russian Academy of Sciences, Petrozavodsk, 51–53. [In Russian]

Pavlovsky EN (Ed.)(1955) Pests of the forest. Reference book: in 2 vols. Vol. 2. Academy of Sciences of the USSR, Moscow-Leningrad, 1097 pp. [In Russian]

Pfeffer A (1995) Zentral- und westpaläarktische Borken- und Kernkäfer (Coleoptera: Scolytidae, Platypodidae). Pro Entomologia & Naturhistorisches Museum, Basel (CH), 310 pp.

Raffa KF (2001) Mixed messages across multiple trophic levels: the ecology of bark beetle chemical communication system. Chemoecology 11: 49–65. https://doi.org/10.1007/PL00001833

Raffa KE, Gregoire JC, Lindgren BS, Vega F, Hofstetter R (2015) Natural History and Ecology of Bark Beetles. Bark beetles biology and ecology of native and invasive species: 1–40. https://doi.org/10.1016/B978-0-12-417156-5.00001-0

Repe A, Kirisits T, Piskur B, De Groot M, Kump B, Jurc M (2013) Ophiostomatoid fungi associated with three spruce-infesting bark beetles in Slovenia. Annals of Forest Science 70: 717–727.

Scherbakov AN, Nikitsky NB, Polevoi AV, Humala AE (2013) On the beetle fauna of "Pasvik" Nature Reserve (Insecta, Coleoptera). Vestnik Moskovskogo gosudarstvennogo universiteta lesa – Lesnoi Vestnik 6(98): 16–21. [In Russian with English abstract]

Stark VN (1932) A guide to accounting for forest damage. 2nd ed. Selkhozgiz, Moscow, Leningrad, 358 pp. [In Russian]

Stauffer C, Zuber M (1998) *Ips amitinus* var. *montana* (Coleoptera, Scolytidae) is synonymous to *Ips amitinus*: a morphological, behavioral and genetic re-examination. Biochemical Systematics and Ecology 26: 171–183. https://doi.org/10.1016/S0305-1978(98)80004-5

Voolma K, Mandelshtam MJ, Shcherbakov AN, Yakovlev EB, Ounap H, Suda I, Popovichev BG, Sharapa TV, Galasjeva TV, Khairetdinov RR, Lipatkin VA, Mozolevskaya EG (2004) Distribution and spread of bark-beetles (Coleoptera: Scolytidae) around the Gulf of Finland: a comparative study with note on rare species of Estonia, Finland and North-Western Russia. Entomologica Fennica 15(4): 198–210. https://doi.org/10.33338/ef.84222

Witrylak W (2008) Studies of the biology, ecology, phenology, and economic importance of *Ips amitinus* (Eichh.) (Col., Scolytidae) in experimental forests of Krynica (Beskid Sadecki, southern Poland). Acta Scientiarum Polonorum Silvarum Colendarum Ratio et Industria Lignaria 7(1): 75–92.