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Illustrated key to bark beetle species of the genus *Ips* DeGeer (Coleoptera: Curculionidae, Scolytinae) of Russia based on their damage to the bark

Иллюстрированный определитель короедов рода *Ips* DeGeer Росси по повреждениям

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Key words: Coleoptera, Scolytinae, bark beetles, *Ips,* damages, egg gallery systems, larval mines.
Ключевые слова: Coleoptera, colytinae, короеды, *Ips,* повреждения, маточные ходы, личиночные ходы.

Abstract. Each species of the bark beetle genus *Ips* De Geer imparts typical damage on inner surfaces of bark, in terms of size and pattern, which can be used for species identification of this pest. A key to the identification of *Ips* species based on an analysis of the type of damage is presented.

Резюме. Каждый вид короеда рода *Ips* De Geer оставляет на внутренней поверхности коры характерные повреждения. По особенностям и линейным размерам этих повреждений можно достоверно идентифицировать виды этого рода.

The bark beetles leave lesions on the inner surface of the bark and on the sapwood that have characteristic distinctive features for each taxon. At the beginning of infestation, identification of the species by its gallery systems is significantly difficult: the egg gallery is in its infancy, the larval mines are not developed (Fig. 1). In this case, it is necessary to collect imago, which should then be determined by the characteristic features. It is possible to reliably identify a particular bark beetle by damage when it is in the following stages: older larvae, pupae or young beetles. It is also difficult to identify beetles by damage on already used bark trunks and branches when the bast and sapwood are colored with mycelium, and the gallery systems are difficult to distinguish due to the damage to other xylophages (buprestids, cerambycides, etc.) in the form of matted tunnels, clogged with wood dust and mycelium (Fig. 2).

There are general patterns in the nature of damage to coniferous species by bark beetles. In the area of thick bark (usually in the base part of the trunk), the system of galleries is weakly imprinted on the sapwood, while on the inner surface of the bark a distinct pattern of the gallery system is visible (*Ips sexdentatus* Boerner, 1767, *Tomicus piniperda* (Linnaeus, 1758) (Figs 8–10). In the area of thin bark, the tunnels are more clearly imprinted on the sapwood (Figs 3–7).

There are 37 valid *Ips* genus species are present in all countries where plants of *Pinus* and *Picea* genera occur naturally [Douglas et al., 2019]. All species of the genus *Ips* develop on coniferous trees of the family Pinaceae, especially on *Pinus* (pine), *Picea* (spruce), *Larix* (larch) and *Abies* (fir) [Cognato, 2015; Wood, Bright, 1992].

On the territory of the Russian Federation there are 6 main species of bark beetles of the genus *Ips*: *I. acuminatus* (Gyllenhall, 1827) — sharp-toothed bark beetle; *I. amitinus* (Eichhoff, 1871) — small spruce bark beetle; *I. subelongatus* (Motschulsky, 1860) — larch bark beetle; *I. duplicatus* (Sahlberg, 1836) — northern bark beetle; *I. sexdentatus* (Boerner, 1767) — six-toothed bark beetle; *I. typographus* (Linnaeus, 1758) — spruce bark beetle.

It should be noted that species such as *Ips acuminatus*, *Ips amitinus*, and occasionally *Ips duplicatus* are able to colonize tree branches of different thicknesses in addition to trunks.

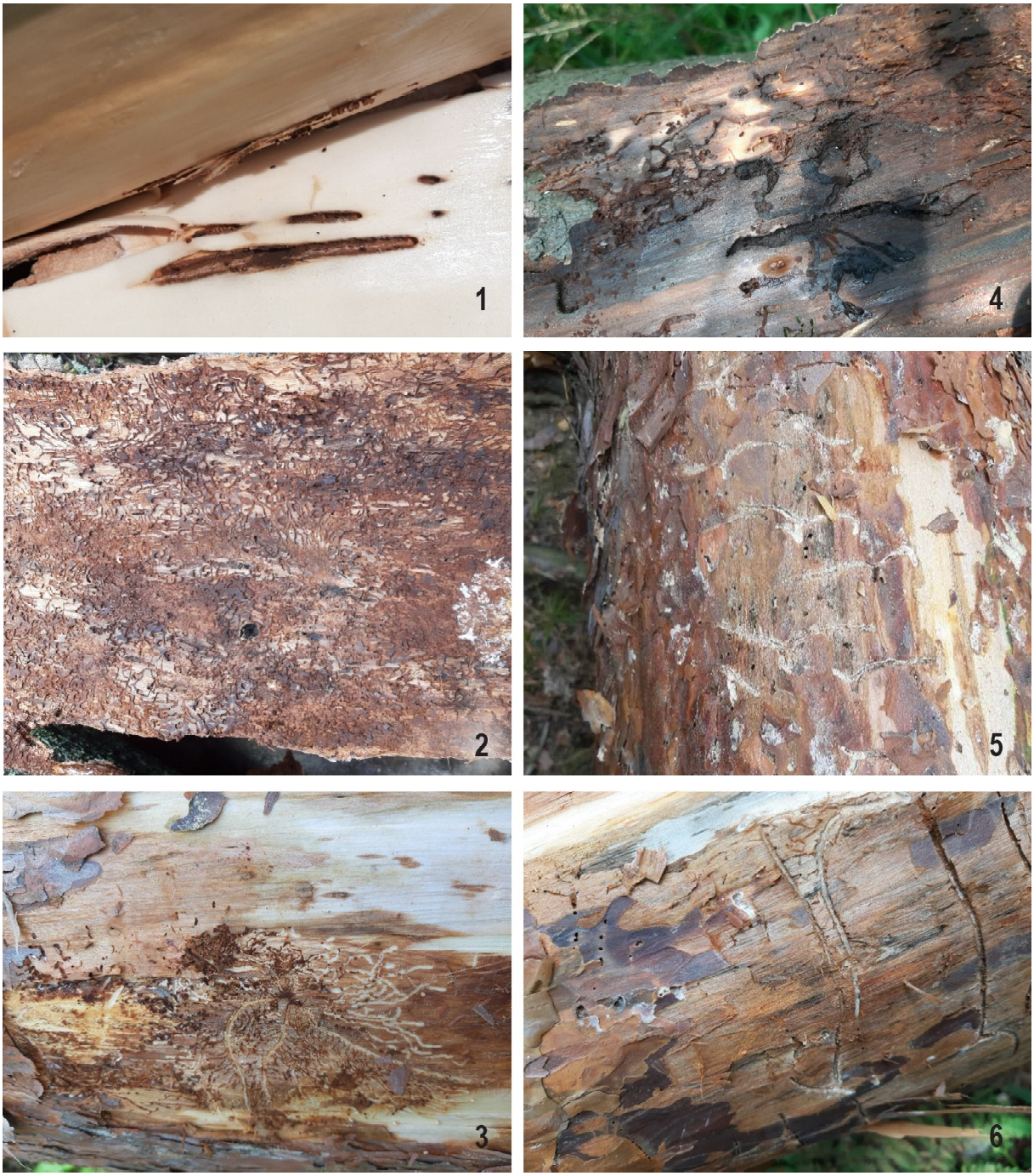
Damage by all bark beetles of the genus *Ips* that are distributed on the territory of the Russian Federation differs from damage caused by other xylophagous insects by the following characteristic features:

— The entire system of galleries is well imprinted on the inner surface of the bark, affecting the sapwood to varying degrees (depending on the thickness of the bark).

— Damage is found on the trunk or branches with a diameter greater than 2.5 cm.

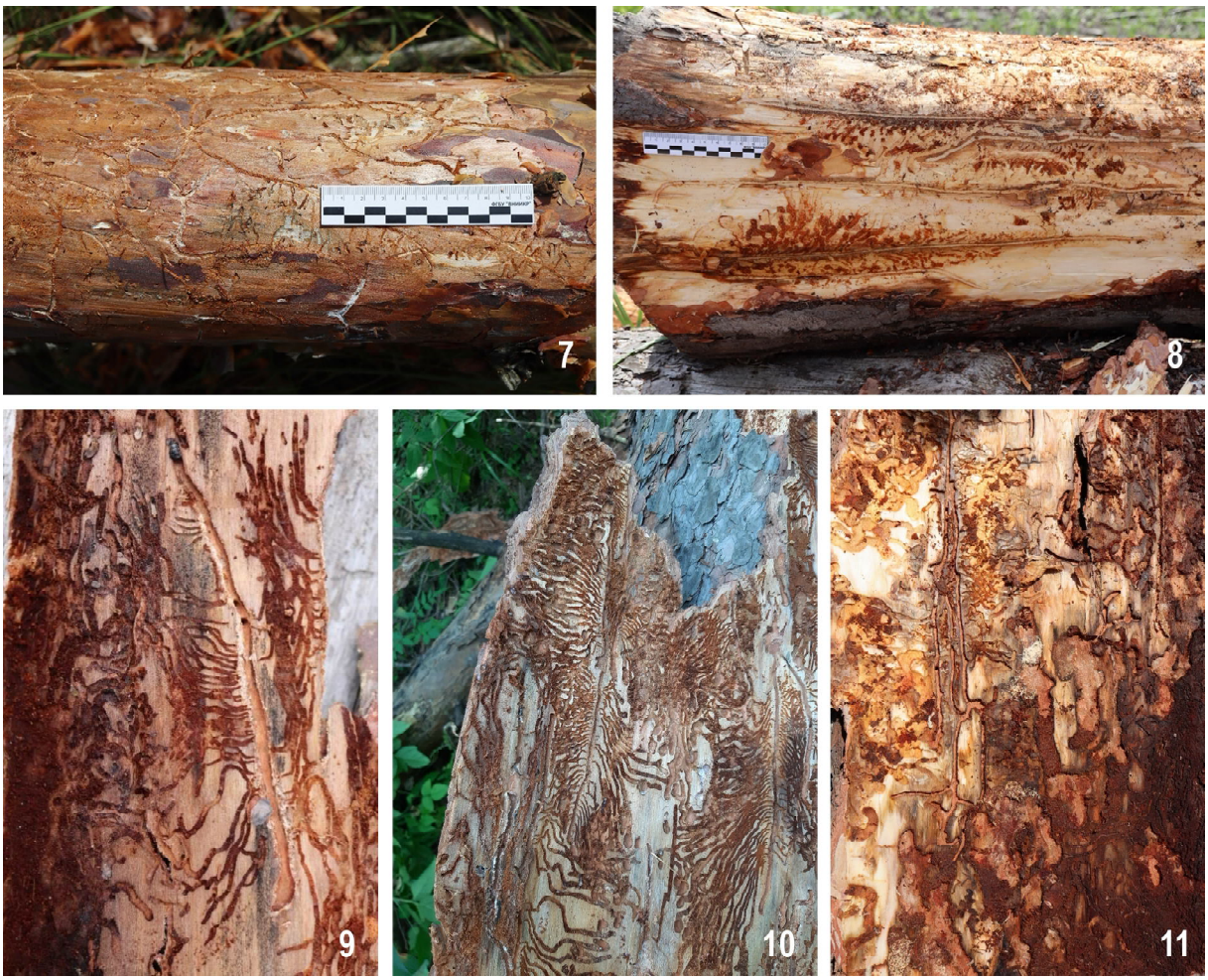
— Damage in the form of long narrow egg galleries from which the gradually expanding larval mines extend away perpendicularly from the egg gallery (Figs 2, 3, 6, 7, 8, 16, 17, 18, 22).

— Egg galleries with a pronounced nuptial chamber (Figs 3, 16, 17) are either clearly visible on the inner



Figs 1–6. Galleries of some bark beetle species. 1 — Rudimentary *Ips typoraphus* egg galleries on the spruce felled by the wind, 2 — gallery systems of *Tomicus piniperda* that are difficult to distinguish on the inner surface of the bark of pine trunk used by bark beetles, 3 — gallery system of *Pityogenes chalcographus*, imprint on the sapwood, 4 — gallery of *Hylurgops glabratus* on the sapwood (spruce), 4 — gallery of *Hylurgops glabratus* spruse's sapwood, 5 — egg galleries of small pine engraver *Tomicus minor* on the trunk of pine tree. Visible pupal cells in the sapwood, 6 — egg galleries systems of *Tomicus minor* on the pine's sapwood. Attempts of settlement and undeveloped galleries of the small pine engraver are visible.

Рис. 1–6. Ходы разных видов короедов. 1 — зачаточные маточные ходы короеда-типографа на ветровальной ели, 2 — трудно различимые ходы *Tomicus piniperda* на внутренней поверхности коры отработанного короедами ствола сосны, 3 — система ходов *Pityogenes chalcographus*, отпечаток на заболони, 4 — ход *Hylurgops glabratus* на заболони (ель), 5 — маточные ходы малого соснового лубоеда *Tomicus minor* на стволе сосны; заметны куколочные колыбельки в заболони, 6 — ходы *Tomicus minor* на заболони сосны.



Figs 7–11. Galleries of some bark beetle species. 7— egg galleries systems of *Ips acuminatus* on the pine's sapwood. Attempts of settlement and undeveloped galleries of the small pine engraver are visible., 8 — gallery of *Ips sexdentatus* on the inner surface of the bark of pine. 9 — egg galleries of *Tomicus piniperda* on the inner surface of the bark of pine, 10 — egg galleries system of *Ips typographus* (imprint on the inner surface of the bark of pine), 11 — egg gallery systems and larval mines of *Ips sexdentatus* (imprints in the bark and sapwood).

Рис. 7–11. Ходы разных видов короедов. 7 — ходы *Ips acuminatus* на заболони сосны, 8 — ход *Ips sexdentatus* на внутренней поверхности коры, 9 — ходы *Tomicus piniperda* на внутренней поверхности коры сосны, 10 — система ходов *Ips typographus* (отпечаток на коре сосны), 11 — система ходов *Ips sexdentatus* (отпечатки в толще коры и на заболони).

surface of the bark (Fig. 10, 26a) and on the sapwood (Fig. 16) or located in the thickness of the bark and are not imprinted on the sapwood (Figs. 18, 19).

— Egg galleries are more than 1.2 mm wide.

— Egg galleries are longitudinal or extend away from the nuptial chamber in a star-like form, then taking a longitudinal direction.

— Larval mines are mostly parallel, rarely intersectional (usually at the end).

Damage to other xylophagous insects that develop on conifers has other distinctive features:

a) Damage is usually on the branches of spruce or fir with a diameter of 0.8 to 3.5 cm in the form of irregularly shaped sites under the bark affecting the sapwood. Sites can be rounded up to 1.5 cm in diameter or elongated up to 3.5 cm in length (Figs 12a, b). Surface larval mines extend away from the sites. Lesions are more common near whorls (genus *Cryphalus* Erichson, 1836).

b) Damage in the form of round, oval, semicircular holes (Buprestidae), deepening into the wood perpendicular to the trunk surface (Fig. 13) (horntails (Hymenoptera, Siricinae), beetles (Coleoptera): Anobiidae, Lymexyllonidae, Bostrichidae, Lyctidae, Cerambycidae, Buprestidae, Melandryidae, genera *Trypodendron* Stephens, 1830 and *Xyleborus* Eichhoff, 1864.

c) Galleries are irregularly shaped, long (up to 20 cm), sinuous, radiating from the poorly visible egg-laying site (Fig. 12b). The galleries are clogged with frass, strongly expand at the edges and end with oval-shaped pupal cells from 0.7 to 1.3 cm long lined with wood fibers (genus *Pissodes* Germar, 1817).

d) Damage is in the form of irregularly shaped sites gnawed in the surface layer of sapwood or wide winding galleries from 0.7 to 3.0 cm wide partially or com-

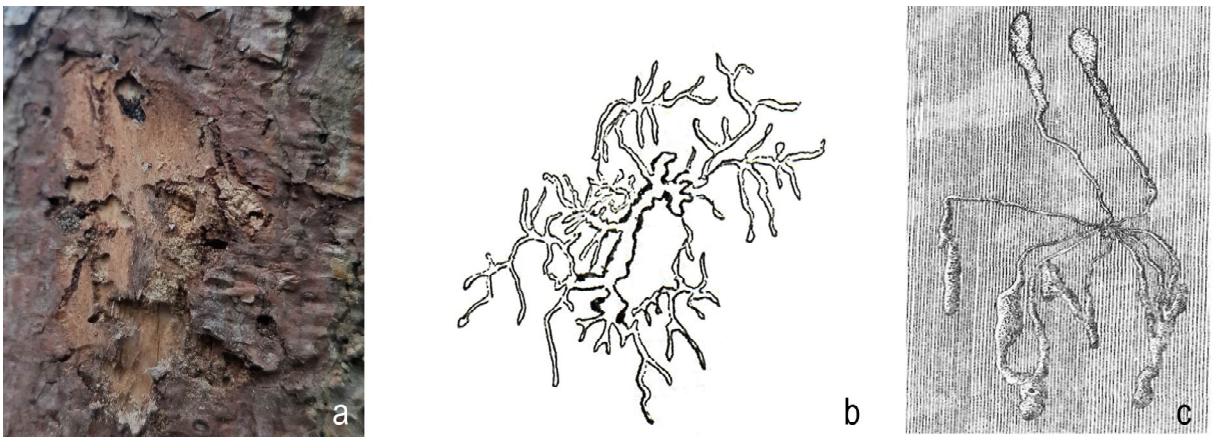


Fig. 12. Damage by bark beetles of the genus *Cryphalus* and pine weevil: a — *Cryphalus saltuarius*; b — *Cryphalus latus* [by Stark, 1952]; c – pine weevil (*Pissodes pini* (Linnaeus, 1758) [by Vorontzov, 1967].

Рис. 12. Ходы короедов-крифалов и сосновой смолёвки: а — таёжного крифала (*Cryphalus saltuarius*), б — широкого крифала (*Cryphalus latus*) [по Старк, 1952], в — сосновой смолёвки (Pissodes pini) [по Воронцову, 1967].

pletely clogged with frass of various density and structure (Figs 14, 15) (Cerambycidae, Buprestidae).

e) Egg galleries have no nuptial chamber. At the base of the egg gallery foot-shaped (Fig. 9) or hooked (Fig. 20) extension can be present (*Tomicus piniperda*, genus *Hylurgops* Leconte, 1876, Fig. 4).

f) In cases where the system of galleries has a nuptial chamber, which are clearly visible on the inner surface of the bark (Fig. 10–11) and on the sapwood (Fig. 16), or located in the thickness of the bark and not imprinted on the sapwood (Figs 18, 19), the width of the egg gallery never exceeds 1.2 mm (genera *Carphoborus* Eichhoff, 1864 (Fig. 16), *Xylechinus* Chapius, 1869, *Polygraphus* Erichson, 1836, *Crypturgus* Erichson, 1836, *Pityophthorus* Eichhoff, 1864).

g) The egg galleries extend away from the nuptial chamber in a transverse direction (Figs. 5, 21, 22) (*Polygraphus proximus* Blandford, 1894, *Tomicus minor*, genus *Pityokteines* Fuchs, 1911, *Xylechinus pilosus* Ratzeburg, 1837 and *Phloeotribus spinulosus* Rey, 1883).

h) In cases where the width of the longitudinal egg gallery exceeds 1.2 mm, the larval mines are mixed up (Figs. 9, 16, 20) (genera *Tomicus* Latreille, 1802, *Hylurgus* Latreille, 1807, *Hylurgops* Leconte, 1876 (except for *Hylurgops glabratus*, whose larval mines start as family ones, but then transform into separate galleries that fan out from the group ones and deepen into the bark (Fig. 4) [Stark, 1952]), *Hylastes* Erichson, 1836, *Dryocoetes* Eichhoff, 1864, *Orthotomicus* Ferrari, 1867).

Key to species of the genus *Ips* by damage to the bark and sapwood of coniferous trees

1. Egg galleries are clogged with frass. At first the egg galleries (from 3 to 12.5 on average) are star-shaped and extend away from the nuptial chamber, then take a longitudinal or

Figs 13–15. 13 — damage by insects that develop exclusively in wood, 14–15 — larval mine of black sawyer beetle *Monochamus galloprovincialis* (imprints on pine's sapwood) (14 — initial stage).

Рис. 13—15. 13 — повреждения насекомых, развивающихся исключительно в древесине, 14–15 — личиночный ход чёрного соснового усача *Monochamus galloprovincialis* на заболони сосны (на рис. 14 — начальная стадия).

somewhat oblique direction. Their length is usually 10–20 cm, but can reach 50 cm. The width of the egg gallery is 2 mm (Fig. 23). The egg gallery systems are usually well are imprinted on the sapwood. The insect settles in the area of thin bark on the tops and large branches. The egg galleries can often be seen through the bark and are clearly visible from the outside (Fig. 24) ..... ***I. acuminatus***

— The egg galleries are free of frass 2

2. The egg galleries are initially star-shaped (near the nuptial chamber), then take a longitudinal direction. Egg galleries are from 3 to 7. The egg gallery system is very similar to *Ips acuminatus*, but they are free of frass. Their length is up to 18 cm. Width is 1.8–2.1 mm. The egg and larval galleries are usually well imprinted on the sapwood. (Fig. 25). The insect settles on branches and trunks with a diameter of 1 to 20 cm. Prefers trunk areas with thin bark (tops, branches, young trees) ..... ***I. amitinus***

— The egg galleries are always longitudinal (along the fibres of the wood). Their number is from 1 to 5 3

3. The width of the egg gallery does not exceed 2 mm. The egg gallery length is 7–10 cm. Larval mines are sparse, serpentine; in most cases they extend away from the egg gallery and alternate to the right and left. They end under the bark with pupal cells. There are usually 2, rarely egg galleries 3–5 egg galleries (Fig. 26a). The egg galleries are straight, but may bend in cases of insect settlement on a pine tree (Fig. 26b). Under the thick bark, the nuptial chamber is located in the thickness of the bark, without being imprinted on the sapwood (Fig. 19) ..... ***I. duplicatus***

— The width of the egg gallery exceeds 2 mm. The length of the egg gallery is more than 10 cm 4

4. The width of the egg gallery is 2.2–3.0 mm, the length is up to 16 cm (very rarely up to 40 cm). Larval mines are densely spaced, relatively short, and usually not tangled (Figs 10, 27) ..... ***I. typographus***

— The width of the egg gallery is 2.8 mm or more 5

5. The width of the egg gallery is 2.8–3.1 mm, its length is up to 30 cm [Stark, 1952]. On average, egg galleries are 12–17 cm long [Izhevsky et al., 2005]. Larval mines are short, they do not reach sapwood; the insect can deeply cut into it only when it settles under the thin bark (Fig. 28) ..... ***I. subelongatus***

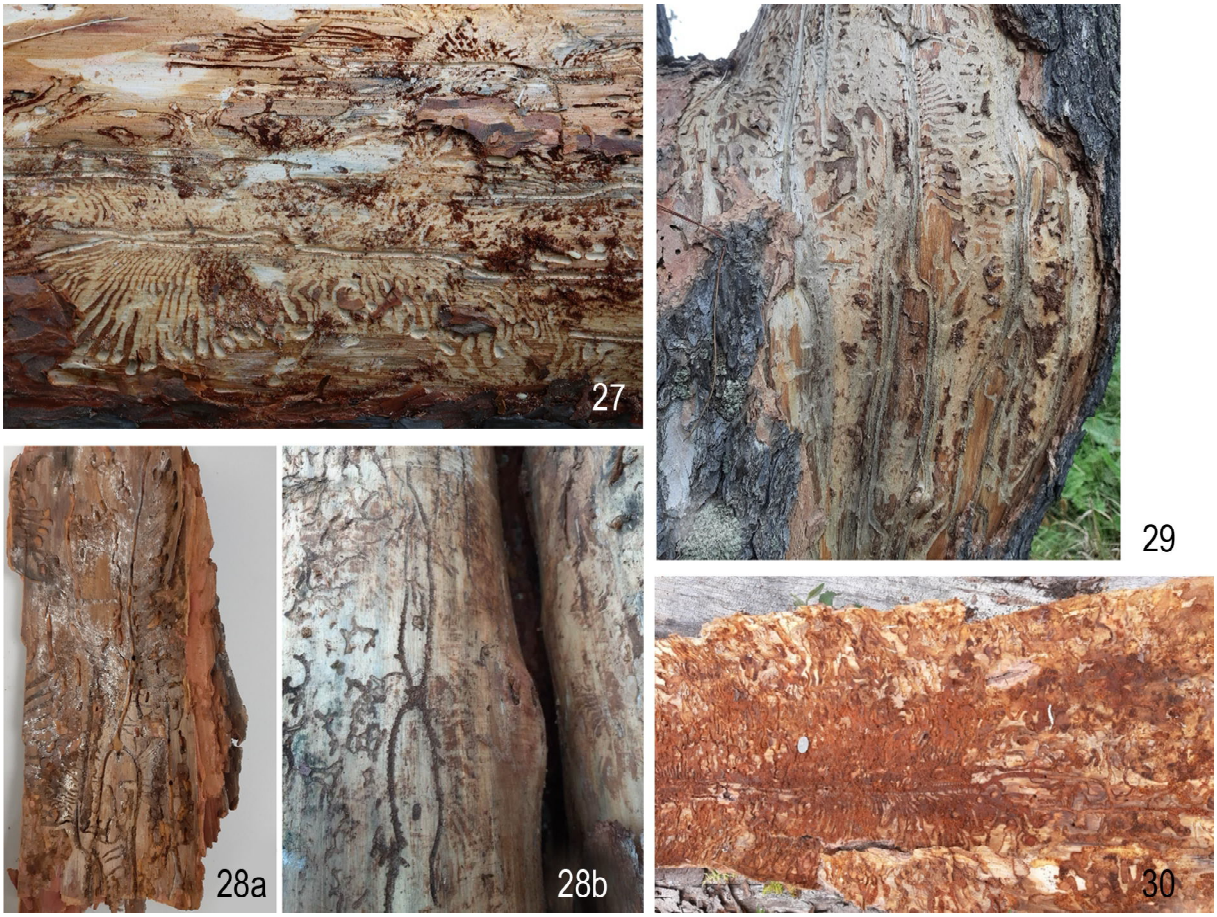
— The egg galleries are no less than 3.2 mm wide, their length can reach 50 cm, and up to 70 cm in some cases (on average 40 cm). The width of the egg gallery is usually about 4 mm. 2–4 egg galleries extend away from the nuptial chamber in the longitudinal direction. Larval mines are transverse, relatively short and rather sparse, rapidly expanding. Sometimes their ends merge with each other (Figs 8, 11, 29). Pupal cells are located under the bark (Fig. 31) ..... ***I. sexdentatus***

Figs 16–19. 16 — egg gallery system and larval mines of *Carphoborus cholodkovskyi*, imprints on the pine's sapwood (drawing by A.V. Shamaev), 17 — gallery system of *Pityogenes chalcographus* with a pronounced nuptial chamber, 18–19 — gallery system of *Ips duplicatus*imprint on the sapwood: 18 — with an almost imperceptible nuptial chamber, 19 — imprint on the inner surface of the bark of a spruce (the nuptial chamber is located completely in the thickness of the bark).

Рис. 16—19. 16 — система ходов *Carphoborus cholodkovskyi*, отпечаток на заболони (рис. Шамаева А.В.), 17 — система ходов *Pityogenes chalcographus* с ярко выраженной брачной камерой, 18–19 — система ходов *Ips duplicatus*: 18 — отпечаток на заболони с почти незаметной брачной камерой, 19 — отпечаток на внутренней поверхности коры (брачная камера располагается полностью в толще коры).

Figs 20–26. Egg gallery systems and larval mines of bark beetle species: 20 — *Tomicus piniperda* on the inner surface of the bark, 21 — *Polygraphus proximus,* imprints on the fir's sapwood, 22 — *Pityokteines curvidens* Germ. [by Pfeffer, 1994], 23 — *Ips acuminatus,* clogged with frass, 24 — *Ips acuminatus,* which is visible through the thin bark of pine tree, 25 — *Ips amitinus,* 26 — *Ips duplicatus:* a – on the inner surface of the bark; b – imprints on the pine's sapwood.

Рис. 20–26. Ходы разных короедов: 20 — *Tomicus piniperda* на внутренней поверхности коры, 21 — уссурийского полиграфа *Polygraphus proximus,* отпечаток на заболони пихты, 22 — восточного крючкозубого короеда *Pityokteines curvidens* Germ. [Pfeffer, 1994], 23–24 — ходы вершинного короеда *Ips acuminatus: 23* — забитые буровой мукой, 24 — заметные сквозь тонкую кору сосны, 25 — *Ips amitinus,* 26 — *Ips duplicatus:* a — отпечаток на внутренней поверхности коры сосны, b — отпечаток на заболони сосны.



Figs 27–30. Egg gallery systems and larval mines of bark beetle species: 27 — *Ips typographus* on pine's sapwood, 28 — *Ips subelongatus*: a — on the inner surface of the bark (photo by E.N. Akulov); b — on the sapwood, 29 — *Ips sexdentatus* on the pine's sapwood, 30 — *Ips sexdentatus* on the inner surface of the bark.

Рис. 27–30. Ходы разных видов жуков-короедов: 27 — короеда-типографа на заболони сосны, 28 — лиственничного короеда: а — на внутренней поверхности коры сосны (фото Е.Н. Акулова), б — на заболони, 29 — *Ips sexdentatus*, отпечаток заболони сосны, 30 — *Ips sexdentatus*, отпечаток на внутренней поверхности коры сосны.

Remarks

Ips acuminatus (Gyllenhal, 1827)

Figs 23, 24.

Distribution. Russia (European part, Caucasus, Siberia, the Far East), Belarus, Ukraine, Moldova, Transcaucasia, Kazakhstan; Europe, Asia Minor, Syria, Northern Mongolia, Korean Peninsula, Northern China, Japan.

Notes. A favorite host plant is *Pinus sylvestris*. This bark beetle also inhabits pine trees of other species: *P. funebris*, *P. austriaca*, *P.nigricans*. It also damages cedar *P. koraiensis*, *P. cembra*, *P. sibirica*, less often spruce *Picea obovata*, *P. abies*, *P. ajanensis*, *P. koraiensis* and *P. orientalis*. It is also recorded on fir *Abies sibirica*, *A. nephrolepis*, *A. holophylla*, *A. sachalinensis* and *A. nordmanniana*, larch *Larix decidua*, *L. olgensis*, *L. sibirica* and *L. gmelinii*, and some other plants [Izhevsky et al., 2005].

Ips amitinus (Eichhoff, 1871)

Fig. 25.

Distribution. Great Britain, Greece, Iran, Ireland, Morocco, Norway, Turkey, France (Corsica only), Croatia [Izhevsky et al., 2005], Finland, Sweden [Kerchev et al., 2019].

Notes. Damaged (forage) woody plants: Norway spruce, rarely pine (Scots pine and some others), *Abies alba*, *Larix decidua* [Izhevsky et al., 2005]. In Western Siberia, *I. amitinus* was first identified in 2019. Many bark beetles are found on *Pinus sibirica* Du Tour in the near-village cedar forests of the Tomsk and Kemerovo regions [Kerchev et al., 2019].

Ips duplicatus (Sahlberg, 1836)

Fig. 18, 26a,b.

Distribution. Great Britain, Greece, Iran, Ireland, Turkey [Izhevsky et al., 2005], Norway, Finland, Sweden, Germany, Czech Republic, Slovakia, Austria, Poland [Stark, 1952]. Russia: European part (in the area of common spruce distribution), Siberia, the Far East (including Sakhalin); Belarus, Ukraine, Northern Kazakhstan, Mongolia, China, Japan [Izhevsky et al., 2005].

Notes. Damaged (forage) woody plants: *Picea abies*, *P. obovata*, *P. ajanensis*, *P. koraiensis*; more rarely, *Pinus koraiensis* and *P. sibirica*; even less often fir *Abies sibirica* and *A. holophylla*, larch *Larix sibirica* and *L. gmelinii* [Izhevsky et al., 2005].

Ips typographus (Linnaeus, 1758)

Fig. 10, 27.

Distributed. Russia (European part (partially excluding the steppe zone, the Caucasus, Siberia, and the Far East (including Sakhalin and the Southern Kuril Islands)); Belarus, Ukraine, Transcaucasia, Kazakhstan; Northern Africa, Europe, Turkey, Mongolia, Korea, North. China, Japan. Introduced to the Northern American [Izhevsky et al., 2005)]

Notes. Damaged (forage) woody plants: the main forage plants are spruce *Picea ajanensis*, *P. orientalis*, *P. abies*, *P. koraiensis*, *P. obovata*, *P. glehnii*, rarely pine. In the European part of the habitat, in the Caucasus and Siberia, it damages Scots pine, in the Far East — Korean cedar. In addition, it develops on fir *Abies holophylla*, *A. nephrolepis*, *A. nordmanniana*, *A. sibirica*, *A. alba*, *A. sachalinensis*, on other species of pine *Pinus cembra* and *P. sibirica*, on larch *Larix decidua*, *L. sibirica* and *L. gmelinii* [Izhevsky et al., 2005]. One of the most harmful species of bark beetles. It is found in very large numbers in logging areas, forming breeding centers.

Ips subelongatus (Motschulsky, 1860)

Fig. 28.

Distribution. Russia (Northern areas, partly in the West and East of European part, Siberia, the Far East (including Sakhalin and Southern Kuril Islands)); Ukraine, Kazakhstan; Europe, Mongolia, North-Eastern China, Korean Peninsula, Japan, Taiwan.

Notes. On the trunks of lying trees, the egg galleries may have a transverse direction [Izhevsky et al., 2005].

Ips sexdentatus (Boerner, 1776)

Fig. 8, 11, 29, 31.

Distribution. Russia (European part, the Caucasus, Siberia, the Far East); Belarus, Ukraine, Moldova, Transcaucasia, Kazakhstan; Europe, Asia Minor (Turkey), Mongolia, China, Korea, Japan; Thailand, Myanmar (Burma).

Notes. The largest species of the genus on the territory of the Russian Federation. It damages mainly old large sized pine trees. It is able to populate all other coniferous species, except for juniper. Additional feeding mines (Fig. 31) are gnawed out in places of development and have the form of randomly intertangling channels.

Fig. 31. Pupal cells and additional feeding mines of hatched *Ips sexdentatus* beetles, an imprint on the inner surface of pine bark (photo by A.A. Chalkin).

Рис. 31. Куколочные колыбельки и ходы дополнительного питания отродившихся жуков *Ips sexdentatus*, отпечаток на внутренней поверхности коры сосны.

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