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An illustrated guide to distinguish emerald ash borer (*Agrilus planipennis*) from its congeners in Europe

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Emerald ash borer (EAB) *Agrilus planipennis* is native to East Asia and has recently become a devastating alien pest of ash trees in North America and European Russia. There is no doubt that the pest will spread to other European countries. Early detection and identification of this damaging pest is crucial for minimizing its potential negative economic and ecological impacts. There are about 87 species of the genus *Agrilus* in Europe, but there are no guides for identification, that include *Agrilus planipennis* and native species. We present here the first guide to distinguish emerald ash borer from similar native European *Agrilus* species based on easily detectible external morphological characters suitable for use by non-taxonomists. The main diagnostic characters of EAB adults are: large size (12–15 mm), head and pronotal disc deeply impressed, pronotal sides converging toward anterior margin, elytra mostly brightly emerald, without tomentose spots, pygidium bearing apical process. The main diagnostic character of EAB larvae is the bell-shaped abdominal segments 1–7.

Introduction

Emerald ash borer (EAB), *Agrilus planipennis* Fairmaire, 1888 is the most destructive pest of ash trees in the world (Straw *et al.*, 2013; Herms and McCullough, 2014; Chamorro *et al.*, 2015; Kelnarova *et al.*, 2018). This previously little known East Asian species was first detected in the USA and Canada in 2002 (Haack *et al.*, 2002; Klimaszewski *et al.*, 2017), and in European Russia (Moscow City) in 2003 (Izhevskii, 2007; Volkovitsh and Mozolevskaya, 2014). To date, EAB has spread to five provinces of Canada, 35 states of the USA (EAB-Info, 2018) and 11 provinces of Central European Russia and killed millions of ash trees (Haack *et al.*, 2002; Straw *et al.*, 2013; Herms and McCullough, 2014; Orlova-Bienkowskaja, 2013, 2014; Volkovitsh and Mozolevskaya, 2014; Orlova-Bienkowskaja and Bieńkowski, 2016; EAB-Info, 2018). This insect pest is a threat to ash trees all over Europe, and there is no doubt that it will spread from Russia to other European countries (Baranchikov *et al.*, 2008; Wessels-Berk and Scholte, 2008; EPPO, 2017; Valenta *et al.*, 2015, 2017). The probability of its detection in Belarus, Ukraine, Estonia, Latvia and Lithuania by 2022 is estimated as 15–40 per cent (Orlova-Bienkowskaja and Bieńkowski, 2018).

The Buprestid genus *Agrilus* Curtis, 1825 is the most speciose genus in the animal kingdom comprising more than 3000 species worldwide (Jendek and Grebennikov, 2011; Jendek and Poláková, 2014; Chamorro *et al.*, 2015; Kelnarova *et al.*, 2018). There are about 87 species from 12 subgenera in the European fauna, with 43 species occurring in European Russia (Kubáň *et al.*, 2006).

The subgeneric position of some species, including *A. planipennis*, is still unclear. Alexeev (1998) attributed *A. planipennis* to the subgenus *Uragrilus* Semenov, 1935 (type species – *Agrilus guerini* Lacordaire, 1835). Jendek and Grebennikov (2011) attributed it to the East-Asian *cyaneoniger* species-group. An incongruence of EAB with *Uragrilus* species was supported by larval morphology (Chamorro *et al.*, 2012). The molecular phylogeny of *Agrilus* (Kelnarova *et al.*, 2018) revealed the close relation of *A. planipennis* to two Oriental species from Vietnam, but this topology has very low statistical support.

Emerald ash borer has no closely related species in the European fauna. However, identification of this notorious pest is not easy. In particular, in Moscow, beetles were first identified only in 2005, 2 years after the first findings (Volkovitsh, 2007; Volkovitsh and Mozolevskaya, 2014). There is still no guide to distinguish *A. planipennis* from its European congeners. The identification key and diagnoses for East-Asian species and species-groups of *Agrilus* by Chamorro *et al.* (2015) are not appropriate for European species. Recently, a first molecular phylogeny of northern hemisphere representatives of the genus *Agrilus* with DNA barcode database based on three mitochondrial markers and comprising about 100 species was published (Kelnarova *et al.*, 2018) as an attempt to build a reliable tool for identification of all stages of the species of this enormous genus. However, this valuable contribution is only a first step

based on a rather limited sample and molecular identification cannot replace morphological methods, which are simpler, less expensive and can be used in the field for quick identification.

The main objective of this study was to compile a guide to distinguish *A. planipennis* (both adults and larvae) from similar sized European species of the genus *Agrilus* based on the most appropriate and simple diagnostic characters which are suitable for use by non-taxonomists, primarily by professional tree managers in rural and urban settings.

Methods

We examined more than 200 adult specimens of nine mainly similar sized or ash feeding *Agrilus* species native to Europe and approximately 30 specimens of their larvae, as well as nearly 50 adults and 18 specimens of larvae of *A. planipennis* mainly from the territory of the European Russia deposited in the collections of Zoological Institute RAS and A.N. Severtsov Institute of Ecology and Evolution RAS, and revealed the most reliable diagnostic characters for their identification. Images were taken using a Canon EOS 70D digital camera, montaged using Helicon Focus software and subsequently processed using Photoshop. Morphological terminology used in this work is adopted from Jendek and Grebennikov (2011) and Chamorro *et al.* (2015) for adults, and Chamorro *et al.* (2012) for the larvae. The morphological features of both adults and larvae used in the guide are basic characters used in the taxonomic descriptions and keys of *Agrilus* (Alexeev, 1960, 1979, 1981, 1998; Jendek & Grebennikov, 2011; Chamorro *et al.*, 2012, 2015).

Results

Given the large size of *A. planipennis* adults (usually 12–15 mm), it made sense to compare it only with the largest (body length more than 10 mm) species of European *Agrilus*, which included *Agrilus* (*Agrilus*) *suvorovi* Obenberger, 1935, *A.* (*Anambus*)

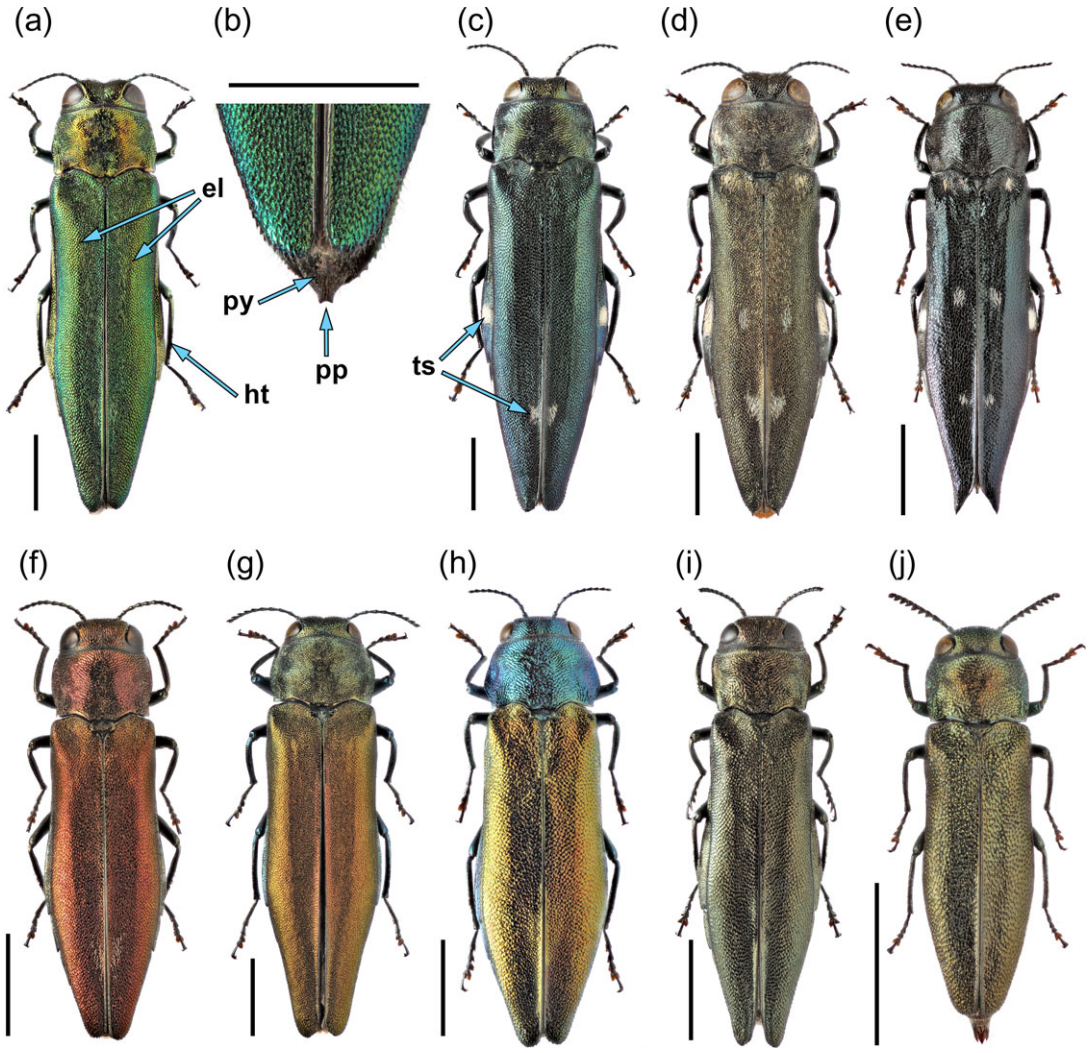

Figure 1 Emerald ash borer, *A. planipennis* and its European congeners: (a, b) *A. planipennis* (Russia: Moscow province, Manikhino): (a) habitus, (b) pygidial process, (c–j) European *Agrilus* spp. habitus: (c) *A.* (*Anambus*) *biguttatus* (Lituania: Kaunas), (d) *A.* (*Uragrilus*) *ater* (Russia: Karachay-Cherkess Republic, Teberda), (e) *A.* (*U.*) *guerini* (Russia: Samara), (f) *A.* (*Sinuatiagrilus*) *sinuatus* (Slovakia: Parkáň), (g) *A.* (*S.*) *mendax* (Russia: Saint-Petersburg), (h) *A.* (*Robertius*) *subauratus* (Ukraine, Kiev), (i) *A.* (*Agrilus*) *suvorovi* (Russia: Primorskii krai, Spassk-Dalnii), (j) *A.* (*Convexagrilus*) *convexicollis* (Germany: Brieselang bei Nauen). el – elytra, ht – hind tibia, pp – pygidial process, py – pygidium, ts – tomentose spots. Scale bars: 2 mm. Photo: A.V. Kovalev.

biguttatus (Fabricius, 1777), *A.* (*Robertius) subauratus* (Gebler, 1833), *A.* (*Sinuatiagrilus) sinuatus* (Olivier, 1790), *A.* (*S.) mendax* Mannerheim, 1837, *A. (Uragrilus) ater* (Linnaeus, 1767) and *A.* (*U.*) *guerini*. We also present a textual diagnosis to distinguish *A. planipennis* from the other European ash feeders, *A.* (*Convexagrilus*) *convexicollis* Redtenbacher, 1847 and *A.* (*C.*) *beauprei* Théry, 1930; however, these species have a much smaller body, so we did not include them in Tables 1 and 2. In addition, because in European Russia *A. convexicollis* occurs on ash trees damaged by *A. planipennis* (Orlova-Bienkowskaja and Volkovitsh, 2015), we added colour pictures of this species. Moreover, some authors mix *A. suvorovi* with *A. viridis* (Linnaeus, 1758) (Jendek and Grebennikov, 2011) or both species are regarded to be the ecological vicariants of the same species (Jendek and Poláková, 2014); for this reason, we placed them in the same column in Tables 1 and 2.

Morphological characters of A. planipennis *adults*

The following features are considered to be characteristic features of EAB adults, but other distinguishing features can also be found within Alexeev (1979, 1998), Jendek and Grebennikov (2011) and Chamorro *et al.* (2015):

- Body (Figure 1a): large ((7.5) 12–15 mm), elongate. Colour: metallic, bright, uni- or bicolorous, emerald, frequently pronotum, head, and abdomen cupreous, rarely entirely violet-blue.
- Head (Figures 2a and 3a): Frons and vertex with deep longitudinal medial impression well seen from above; vertex narrow, bearing concentric punctate striae.
- Pronotum (Figures 3a and 4a): widest at base to mid-length, sides arcuately converging toward anterior corners; disc with deep anterior and posterior medial impressions, covered with

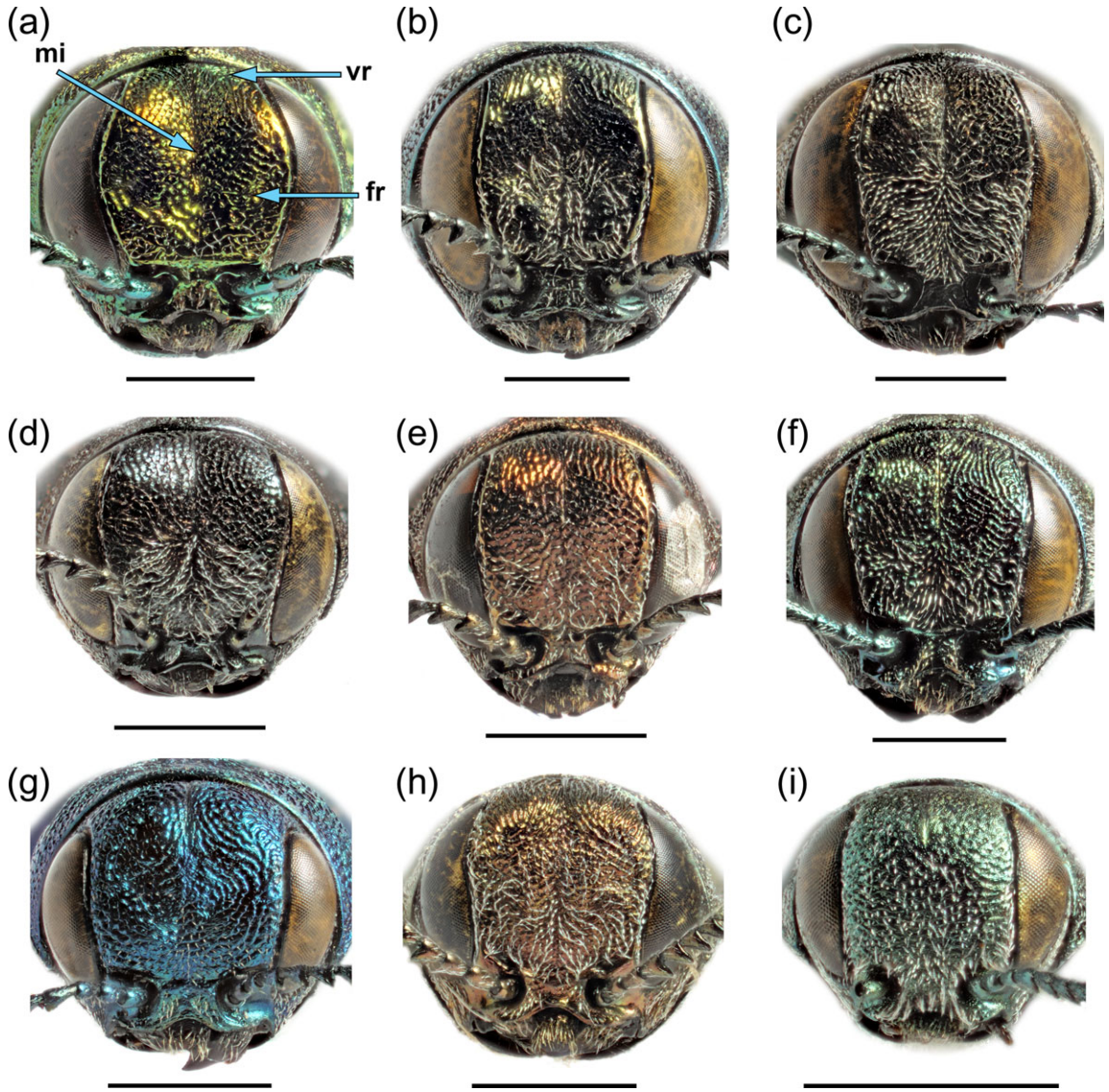

Figure 2 Emerald ash borer, *A. planipennis* and its European congeners, head, frontal view: (a) *A. planipennis*, (b) *A. biguttatus*, (c) *A. ater*, (d) *A. guerini*, (e) *A. sinuatus*, (f) *A. mendax*, (g) *A. subauratus*, (h) *A. suvorovi*, (i) *A. convexicollis*. fr – frons, mi – medial impression, vr – vertex. Scale bars: 1 mm. Photo: A.V. Kovalev.

strongly curved transverse rugosities; marginal and submarginal carinae (Figure 4a: mc, sc) convergent, interspaces broadest medially; prehumeri (Figures 3a and 4a: ph) poorly marked, arcuate, extending to posterior third of pronotal length.
- Elytra (Figure 1a: el) covered with very short, inconspicuous dark hairs and poorly visible groups of light scale-like setae at the beginning of posterior third but without distinct tomentose spots (Figure 1c,d,e: ts); apices arcuate with finely denticulate margins.
- Pygidium (Figure 1b: py) extended into blunt or bifurcate apical process (Figure 1b: pp).
- Abdominal ventrites without distinct tomentose spots.
- Hind tibiae with posterior margin sinuate, occasionally with 1–2 triangular projections.
- Aedeagus: tegmen widest submedially, dorsal notch distal, located 1/3 from tegminal apex; phallus wide, apex acute.

Discrimination from other congeners

The most important diagnostic characters of adult *A. plannipennis* are as follows: large body (12–15 mm), head deeply impressed (Figures 2a and 3a: mi), pronotal sides arcuately converging toward anterior corners and disc with deep anterior and posterior medial impressions (Figure 3a: mi), elytra mostly brightly emerald, without distinct tomentose spots (Figure 1a: el), pygidium bearing apical process (Figure 1b: pp). Among European species a pygidial process is also present in representatives of the subgenus *Uragrilus* (*A. ater* and *A. querini*) but they have distinct white tomentose spots dorsally (Figure 1d,e) and

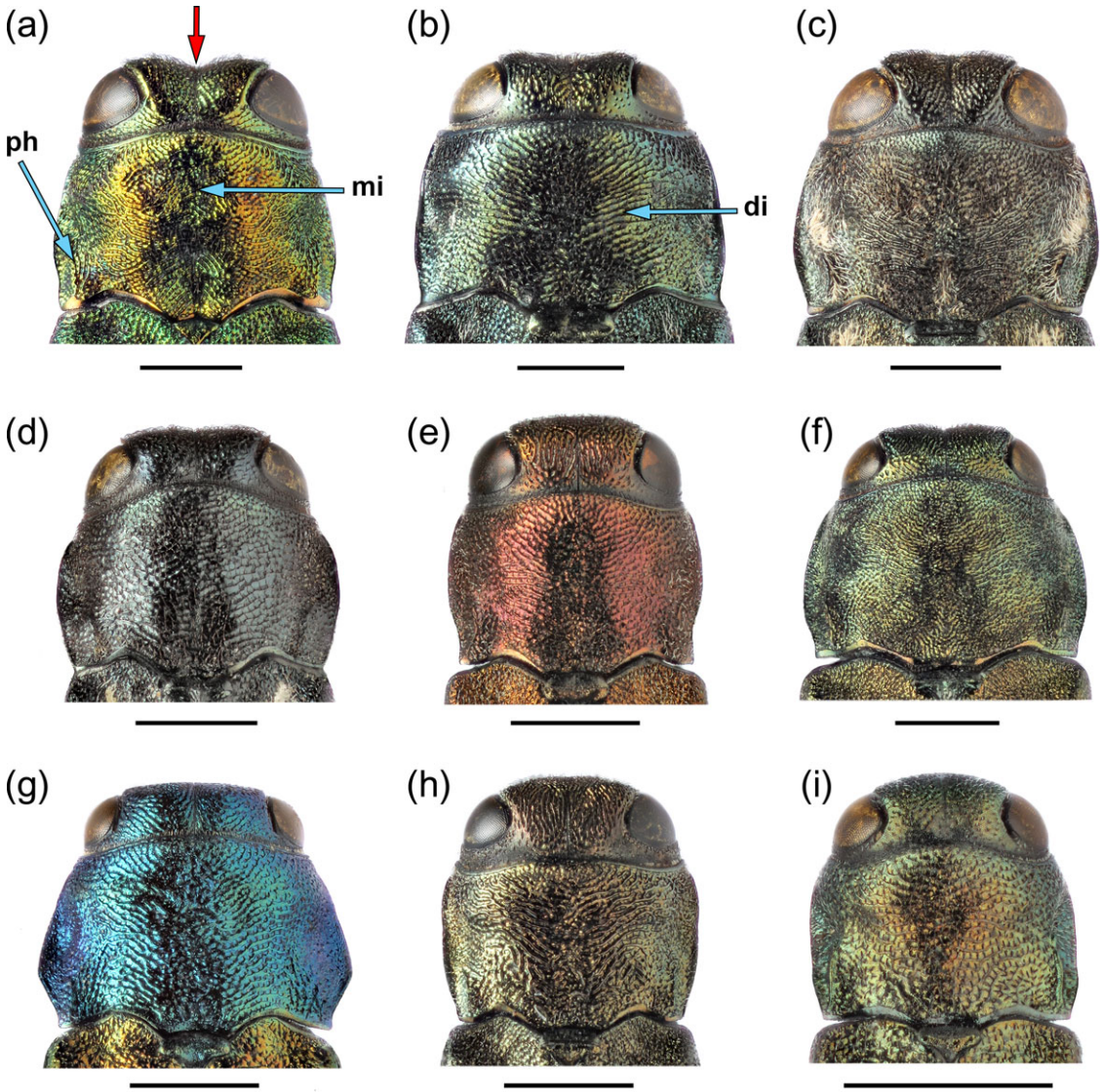

Figure 3 Emerald ash borer, *A. planipennis* and its European congeners, pronotum and head, dorsal view: (a) *A. planipennis*, (b) *A. biguttatus*, (c) *A. ater*, (d) *A. guerini*, (e) *A. sinuatus*, (f) *A. mendax*, (g) *A. subauratus*, (h) *A. suvorovi*, (i) *A. convexicollis*. di – disc, mi – medial impression of pronotum, ph – prehumerus, arrow shows medial impression of head. Scale bars: 1 mm. Photo: A.V. Kovalev.

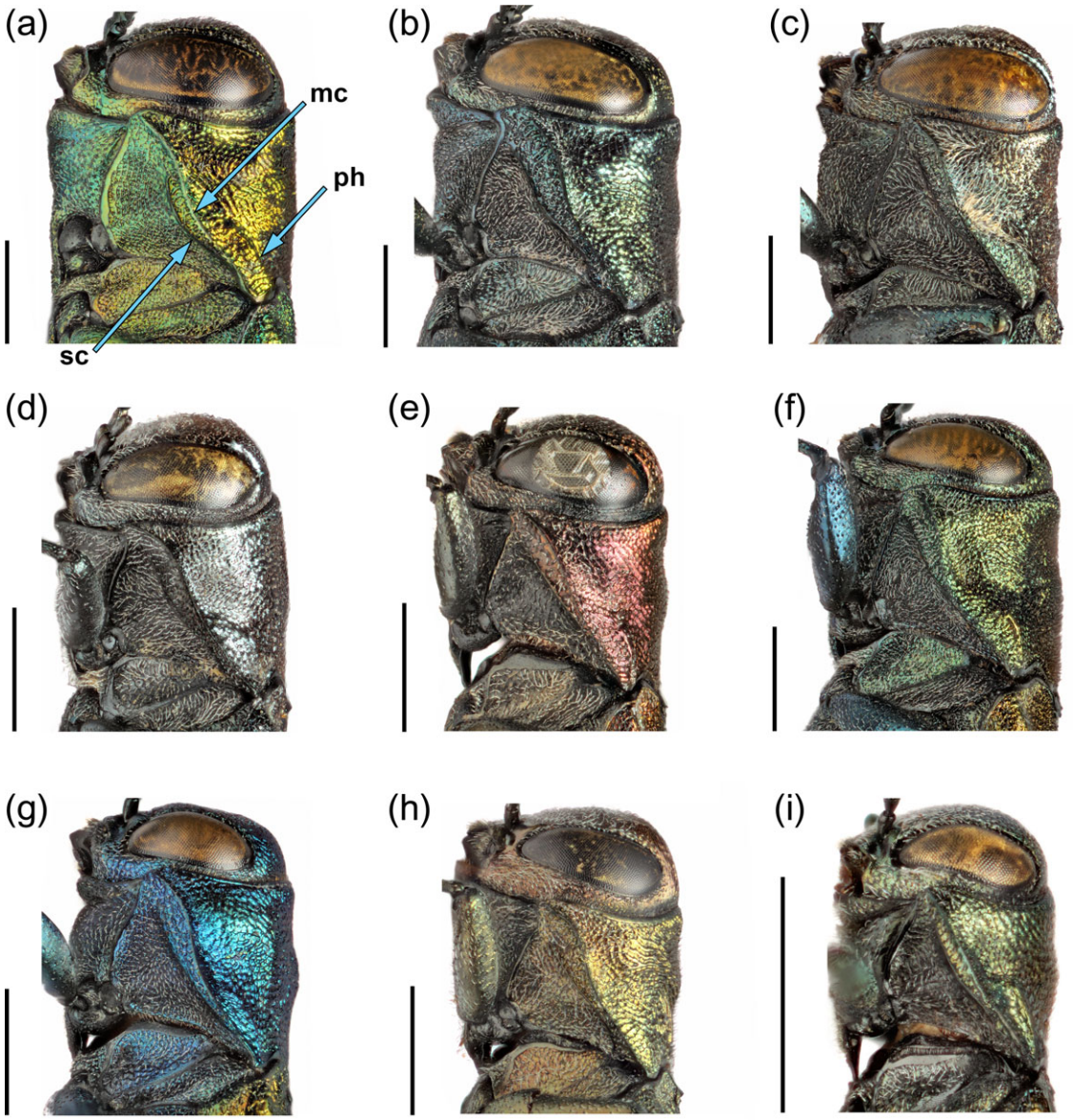

Figure 4 Emerald ash borer, *A. planipennis* and its European congeners, pronotum and head, lateral view: (a) *A. planipennis*, (b) *A. biguttatus*, (c) *A. ater*, (d) *A. guerini*, (e) *A. sinuatus*, (f) *A. mendax*, (g) *A. subauratus*, (h) *A. suvorovi*, (i) *A. convexicollis*. mc – marginal carina, ph – prehumerus, sc – submarginal carina. Scale bars: 1 mm. Photo: A.V. Kovalev.

ventrally; tomentose spots occur also in *A. (Anambus) biguttatus* (Figure 1c: ts) but the pygidial process is lacking. As an exception, the body length of *A. planipennis* may be less than 10 mm (7.5–8 mm according to Haack *et al.*, 2002; Klimaszewski *et al.*, 2017), although we did not observe such small specimens in the examples used to compile this guide. A reliable character to recognize small specimens of *A. planipennis* is the presence of a pygidial process (Figure 1b: pp), which among European species is present only in the representatives of subgenus *Uragrilus* (see above and Table 1).

European ash feeders including *A.* (*Convexagrilus*) *convexicollis* (Figures 1j, 2i, 3i and 4i), that feeds on different genera of Oleaceae, and the west-Mediterranean *A.* (*C.*) *beauprei* which is associated exclusively with *Fraxinus* spp. (Jendek and Poláková, 2014), differ from *A. planipennis* by having a much smaller body (3.5–5.1 mm), a strongly convex head contour in dorsal view (Figure 3i), and lack the pygidial process. Two polyphagous species, *A. roscidus* Kiesenwetter, 1857, and *A. viridis* (Linnaeus, 1758), are also recorded from *Fraxinus* (Jendek and Poláková, 2014). But these species are easy to distinguish from *A. planipennis* by smaller size (4.5–6.5 mm and 5–9 mm, respectively) as well as the absence of pygidial process; additionally, *A. viridis* matches the characters indicated for *A. suvorovi* in Table 1.

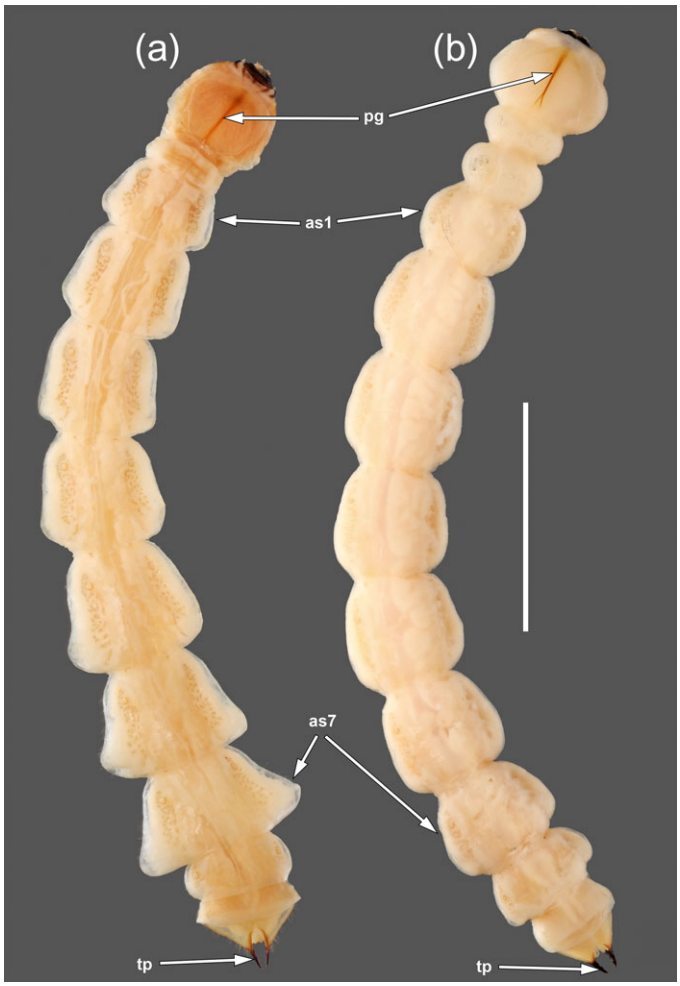

Figure 5 Emerald ash borer, *A. planipennis* and *A. biguttatus*, mature larvae, habitus, dorsal view: (a) *A. planipennis*, (b) *A. biguttatus*. as1, as7 – abdominal segments 1 and 7, pg – pronotal groove, tp – terminal process. Scale bars: 5 mm. Photo: A.V. Kovalev.

Morphological characters of A. planipennis larvae

The following features are considered to be characteristic features of EAB larvae, but other distinguishing features can also be found within Alexeev (1960, 1981), Chamorro *et al.* (2012) and Chamorro *et al.* (2015):

- Abdominal segments 1–7 (Figure 5a: as) bell-shaped.
- Abdominal terminal processes (Figure 5a: tp) narrow, cylindrical, bearing numerous ledges appearing after instar I, and 2–3 internal excretory ducts.
- Posterior contour of the microsetal area on prementum zig-zag-shaped.
- Distance between the anterior margin of prementum and posterior border of microsetal area is equal to approximately 2/5 of the distance from anterior margin to the bases of the apical setae of corner sclerites of labium.
- Pronotal groove (Figure 5a: pg) posteriorly bifurcating, prosternal groove entire.
- Labrum with glabrous anterior margin which is not produced antero-laterally.
- Microspinulae on the mala and internal surface of the maxillary stipes and cardo concentrated subapically.

Discrimination from other congeners

The shape of abdominal segments 1–7 (Figure 5a: as compare with Figure 5b) is unique among known agriline larvae; a combination of other characters also makes it possible to distinguish reliably the EAB larva from those of its European congeners but their use requires special methods of dissecting and microslide mounting.

Conclusion

The presented guide for distinguishing *A. planipennis* adult and larva from similar sized native European *Agrilus* species is aimed at facilitating early detection of this invasive pest in new regions. Early detection and correct identification of a new insect pest is crucial for implementation of effective control measures. Though modern molecular methods of identification are rapidly developing, the classical approach based on morphology remains a principal tool both for primary determination and for verifying the results of DNA-based identifications.

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Conflict of interest statement

None declared.

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Glossary

Adult (after Jendek and Grebennikov, 2011; Chamorro *et al.*, 2015; original).

Aedeagus (male genitalia) – the part of male genital apparatus, including external tegmen and internal phallus (penis).

Apical (pygidial) process (abdomen) (Figure 1b: pp) – see pygidial process.

Disc (pronotum) (Figure 3b: di) – the central part of pronotum.

Elytra [elytron] (Figure 1a: el) – the fore wing in Coleoptera.

Frons (head) (Figure 2a: fr) – the area between the upper margin of eyes and upper margins of antennal fossae.

Marginal carina (pronotum) (Figure 4a: mc) – the lateral keel of pronotum.

Table 1 Adult diagnostic characters of *Agrilus planipennis* in comparison with the indigenous European *Agrilus* species. Subgenus – after Alexeev (1998); species-group – after Jendek and Grebennikov (2011).

Subgenus	(?)	(*Anambus*)	(*Uragrilus*)	(*Uragrilus*)	(*Sinuatiagrilus*)	(*Sinuatiagrilus*)	(*Robertius*)	(*Agrilus*)
Species-group	*cyaneoniger*	*biguttatus*	*spinipennis*	*spinipennis*	*sinuatus*	*sinuatus*	(?)	*viridis*
Species	*planipennis*	*biguttatus*	*ater*	*guerini*	*sinuatus*	*mendax*	*subauratus*	*suvorovi / viridis*
Body length	(7.5) 12–15 mm	8–13 mm	8–12 mm	9–12 mm	8–10 mm	10–12 mm	7–10 mm	7–11 mm
Body dorsally: coloration	Emerald, partly cupreous, rarely violet-blue (Figure 1a)	Green, bluish-green, bronzy-green, blue (Figure 1c)	Blackish-bronze (Figure 1d)	Blue, blackish-blue or violet (Figure 1e)	Copper-bronze-red or golden-bronze (Figure 1f)	Copper-red or copper-bronze (Figure 1g)	Pronotum blue, green or orange; elytra golden-green, orange or blue (Figure 1h)	Olive-green, bluish, bronzy (Figure 1i)
Body: tomentose spots	Poorly visible, on elytra only (Figure 1a)	Well marked dorsally and ventrally (Figure 1c: ts)	Well marked dorsally and ventrally (Figure 1d)	Well marked dorsally and ventrally (Figure 1e)	Poorly visible on elytra only (Figure 1f)	Absent (Figure 1g)	Absent (Figure 1h)	Absent (Figure 1i)
Head: medial impression	Deep (Figure 3a)	Shallow (Figure 3b)	Shallow (Figure 3c)	Shallow (Figure 3d)	Absent (Figure 3e)	Shallow (Figure 3f)	Nearly absent (Figure 3g)	Absent (Figure 3h)
Head: vertex, shape	Narrow (Figures 2a and 3a)	Wide (Figures 2b and 3b)	Narrow (Figures 2c and 3c)	Wide (Figures 2d and 3d)	Wide (Figures 2e and 3e)	Wide (Figures 2f and 3f)	Very wide (Figures 2g and 3g)	Wide (Figures. 2h and 3h)
Head: vertex, punctate striae	Concentric (Figures 2a and 3a)	Arcuate (Figures 2b and 3b)	Concentric (Figures 2c and 3c)	Concentric (Figures 2d and 3d)	Arcuate (Figures 2e and 3e)	Arcuate (Figures 2f and 3f)	Concentric (Figures 2g and 3g)	Straight (Figures 2h and 3h)
Pronotum: sides (dorsal view)	Arcuately converging (Figure 3a)	Nearly arcuate (Figure 3b)	Arcuate or diverging (Figure 3c)	Arcuate or diverging (Figure 3d)	Arcuate or sinuate (Figure 3e)	Arcuate or diverging (Figure 3f)	Arcuate or angulate (Figure 3g)	Diverging or arcuate (Figure 3h)
Pronotum: medial impressions	Deep (Figure 3a)	Shallow (Figure 3b)	Inconspicuos (Figure 3c)	Shallow (Figure 3d)	Shallow (Figure 3e)	Indistinct (Figure 3f)	Indistinct (Figure 3g)	Posterior deep (Figure 3h)
Prehumeri	Poorly defined (Figures 3a and 4a)	Absent (Figures 3b and 4b)	Well defined (Figures 3c and 4c)	Poorly defined (Figures 3d and 4d)	Well defined (Figures 3e and 4e)	Well defined (Figures 3f and 4f)	Poorly defined (Figures 3g and 4g)	Poorly defined (Figures 3h and 4h)
Elytra: apices	Arcuate (Figure 1a)	Arcuate (Figure 1c)	Angular with tooth (Figure 1d)	Tooth-like (Figure 1e)	Arcuate (Figure 1f)	Arcuate (Figure 1g)	Arcuate (Figure 1h)	Arcuate (Figure 1i)
Pygidial process	Present (Figure 1b: pp)	Absent (Figure 1c)	Present (Figure 1d)	Present (Figure 1e)	Absent (Figure 1f)	Absent (Figure 1g)	Absent (Figure 1h)	Absent (Figure 1i)

Table 2 Larval diagnostic characters of *Agrilus planipennis* in comparison with indigenous European *Agrilus* species. Subgenus – after Alexeev (1998); species-group – after Jendek and Grebennikov (2011). Host plans – after Jendek and Poláková (2014) and Cippolini and Peterson (2018).

Subgenus	(?)	(*Anambus*)	(*Uragrilus*)	(*Uragrilus*)	(*Sinuatiagrilus*)	(*Sinuatiagrilus*)	(*Robertius*)	(*Agrilus*)
Species-group	*cyaneoniger*	*biguttatus*	*spinipennis*	*spinipennis*	*sinuatus*	*sinuatus*	(?)	*viridis*
Species	*planipennis*	*biguttatus*	*ater*	*guerini*	*sinuatus*	*mendax*	*subauratus*	*suvorovi/viridis*
Larva: abdominal segments 1–7	Bell-shaped, posterolateral angles produced laterad (Figure 5a)	Subquadrate or elongate, with arcuate or subparallel sides (Figure 5b)	Subquadrate or elongate, with arcuate or subparallel sides	Subquadrate or elongate, with arcuate or subparallel sides	Subquadrate or elongate, with arcuate or subparallel sides	Subquadrate or elongate, with arcuate or subparallel sides	Subquadrate or elongate, with arcuate or subparallel sides	Subquadrate or elongate, with arcuate or subparallel sides
Larva: pronotal groove	Bifurcated (Figure 5a)	Bifurcated (Figure 5b)	Bifurcated	Bifurcated	Bifurcated	Entire	Bifurcated	Entire
Labrum: anterior margin	Glabrous	Setose	Setose	Setose	Glabrous	Glabrous	Glabrous	Glabrous
Prementum: posterior contour of microsetal area along anterior margin	Zig-zag shaped	Zig-zag shaped	Triangular	Separated medially by glabrous space, with arcuate posterior margin	Zig-zag shaped	Triangular	Nearly straight	Triangular
Host plants	Oleaceae: Fraxinus, Chionanthus (US)	Castanea, Fagus, Quercus; Tilia; Populus / Ulmus?	Populus, Salix	Populus, Salix	Crataegus, Cydonia, Malus, Mespilus, Prunus, Sorbus	Sorbus	Populus, Salix	Populus/polyphagous: different species of Betulaceae, Fagaceae, Malvaceae, Myricaceae, Salicaceae (excl. Populus), Sapindaceae,? Rhamnaceae,? Rosaceae,?Ulmaceae

Medial impression (head, pronotum) (Figures 2a: mi and 3a: arrow) – either entire or divided into separate fossae longitudinal depressions in the middle of head and pronotum, sometimes absent.

Phallus (penis) (male genitalia) – the internal piece of aedeagus.

Prehumeri (pronotum) (Figures 3a and 4a: ph) – the short, usually curved keel above the marginal keel and arising from posterior angles of pronotum, occasionally absent (*A. biguttatus*).

Pygidial (apical) process (abdomen) (Figure 1b: pp) – the posterior process of pygidium protruding beyond elytral apices.

Pygidium (abdomen) (Figure 1b: py) – the terminal exposed and sclerotized tergite 7.

Submarginal carina (pronotum) (Figure 4a: sc) – the lateral keel of pronotum situated below and frequently merging with the marginal keel at pronotal base.

Tegmen (male genitalia) – the external piece of aedeagus including phallobase (basal) and parameres (distal).

Tergite (abdomen) – the dorsal abdominal sclerites 1–7 (in *Agrilus*) usually completely covered by elytra.

Tibia (tibiae), hind (Figure 1a: ht) – the part of the leg, articulated proximally with the femur and distally with the tarsus.

Tomentose spots (elytra, pronotum, ventral surface) (Figure 1a: ts) – the spots of scales or dense hairs, frequently covered with wax-like secretions.

Ventrites (abdomen) – the visible ventral abdominal sclerites 1–5 (actually, true sclerites 3–7).

Vertex (head) (Figure 2a: vr) – the area between the imaginary upper margin of frons and anterior margin of pronotum, not separated from frons. In *Agrilus* vertex usually covered with longitudinal, arcuate or concentric rugosities forming by merging punctures.

Larva (after Chamorro *et al*., 2012; Chamorro *et al*., 2015; original)

Abdominal segments (Figures 5a, b: as1, as7) – the larval body segments following after three thoracic segments (pro-, meso- and metathorax), totally, 10 abdominal segments in Buprestid larvae, 10th segment in *Agrilus* and some other Agrilinae bearing terminal processes.

Cardo (maxillaris) (mouth-parts) – the basal segment of maxillae.

Corner sclerites of labium (mouth-parts) – the rod-like sclerites situated at the sides of labial prementum and bearing apical setae and 5 campaniform sensilla.

Excretory ducts (terminal processes) – ducts of excretory glands situated inside abdominal terminal processes.

Labium (mouth-parts) – the lower lip; an unpaired structure forming the ventral part of the mouth; in buprestid larvae composed of the basal postmentum and apical prementum and bearing laterally corner sclerites of labium, which are probably the rudiments of labial palpi.

Labrum (mouth-parts) – the upper lip; an unpaired sclerite, articulated to the clypeus and forming the dorsal part of the mouth.

Mala (mouth-parts) – unpaired 'chewing' lobe sitting on the apex of maxillary stipes, probably merging galea and lacinia.

Maxillae (mouth-parts) – paired lateral appendages of mouth-parts; the maxilla of buprestid larvae consists of a basal cardo and stipes bearing mala internally and a maxillary palp externally.

Microsetal area (prementum) – area covered with microsetae or microspinulae on the ventral (external) surface of prementum, in the larvae of *Agrilus* a single area extending from anterior margin backwards, the shape and length of this area are species specific.

Microspinulae (on mala, maxillary stipes) – semi-transparent microsetae sitting on the cuticular, non-sclerotized tubercles, usually forming the microsetal areas on the surface of mouth-parts and integuments.

Prementum (mouth-parts) – apical part of labium.

Pronotal (Figures 5a, b: pg) and prosternal grooves (prothorax) – heavily sclerotized and entirely or partly coloured grooves in the middle of pronotal (dorsal) and prosternal (ventral) plates of prothorax; in *Agrilus* larvae pronotal groove frequently bifurcating posteriorly.

Stipes (maxillary) (mouth-parts) – main body of the maxilla, basally articulated with cardo and apically bearing mala and maxillary palpus.

Terminal processes (abdomen) (Figure 5a: tp) – paired appendages of the abdominal segment 10, usually having 1–3 ledges on inner surface and 1–3 internal excretory glands with ducts opening on the margins of ledges.

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