Range expansion of Agrilus convexicollis *in European Russia expedited by the invasion of the emerald ash borer,* Agrilus planipennis *(Coleoptera: Buprestidae)*

Marina J. Orlova-Bienkowskaja & Mark G. Volkovitsh

Biological Invasions

ISSN 1387-3547

Biol Invasions
DOI 10.1007/s10530-014-0762-6

Springer

Biol Invasions
DOI 10.1007/s10530-014-0762-6

INVASION NOTE

Range expansion of *Agrilus convexicollis* in European Russia expedited by the invasion of the emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae)

Marina J. Orlova-Bienkowskaja · Mark G. Volkovitsh

Received: 27 April 2014 / Accepted: 26 July 2014

Abstract The jewel beetle *Agrilus convexicollis* Redtenbacher, 1849 (Buprestidae) occurs in many European and North Mediterranean countries and feeds mainly on dying shoots and branches of ash trees (*Fraxinus excelsior*, *F. ornus* and *F. oxyphylla*). A range map of *A. convexicollis* with 479 exact localities from the literature and museum collections is compiled. Historically, this species was not known to be present in the central region of European Russia. Since 2007, however, specimens of *A. convexicollis* have been collected in seven central European Russia localities, effectively expanding the northern border of the previously known range by approximately 665 km. All recently established localities of *A. convexicollis* are within the region invaded by emerald ash borer (*A. planipennis* Fairmaire), an East Asian pest of ashes that was first detected in European Russia in 2003. In addition, almost all *A. convexicollis* specimens from central European Russia (both adults and larvae) were collected from declining *F. pennsylvanica* (an introduced North American ash) infested with *A. planipennis*. This is a new host record for *A. convexicollis*. We suspect that the recent range expansion of *A. convexicollis* in central European Russia has been facilitated by the *A. planipennis* invasion, which has caused widespread decline and mortality of ash trees in the region. This work illustrates how the invasion of one species can facilitate the range expansion of another.

Keywords Buprestidae · *Agrilus convexicollis* · *Agrilus planipennis* · Emerald ash borer · Range expansion · Ash

M. J. Orlova-Bienkowskaja (✉)
A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, 33 Leninskiy Prospect, 119071 Moscow, Russia
e-mail: marinaorlben@yandex.ru

M. G. Volkovitsh
Zoological Institute, Russian Academy of Sciences, Universitetskaya nab. 1, 199034 St. Petersburg, Russia
e-mail: polycest@zin.ru

The jewel beetle *Agrilus convexicollis* Redtenbacher, 1849 (Buprestidae) develops mainly in cambial region of recently dead shoots and branches of ash trees: *Fraxinus excelsior*, *F. ornus* and *F. oxyphylla* (Brechtel and Kostenbader 2002). The larva was previously described by Alexeev (1981) and Bílý (1999). *A. convexicollis* occurs in many European and North Mediterranean countries, from Spain to Azerbaijan. Within its native range in Central Europe, this species prefers lowland and riverine areas but may also be found in forests up to elevations of 500 m (Bílý 2002). While historical records suggest that *A. convexicollis* was not known to be present in central European Russia (Jendek 2006), collections since 2007 indicate its recent establishment at seven localities in the central regions of European Russia (Vlasov 2010;

Published online: 27 August 2014

Nikitsky 2009; original data). We mapped the range of this species and analyzed its dynamics which led us to conclude that the expansion of *A. convexicollis* in central European Russia was likely facilitated by the recent introduction and spread of emerald ash borer, *Agrilus planipennis* Fairmaire, 1888 (Buprestidae), an East Asian pest of ashes that was first detected in European Russia (Moscow region) in 2003.

We compiled distributional information on *A. convexicollis* by examining collection data from 29 museum specimens, and 48 previously published literature sources. Besides this we collected 81 specimens in nature. Data from 479 exact localities were used in our analyses (Tables 1, 2; Fig. 1).

The infestation signs by *A. convexicollis* and A. *planipennis* are different. First, larvae of *A. convexicollis* develop in thin shoots and upper part of the stems (the width of affected stem is usually less than 3 cm), while larvae of *A. planipennis* develop in stems, which are more than 5 cm thick. Second, the exit holes of *A. convexicollis* are <2 mm width, while the exit holes of *A. planipennis* are about 4 mm width. Third, maximal width of larval galleries is about 2 mm in *A. convexicollis* and about 5 mm in *A. planipennis*. The signs of infestation are easily distinguishable, so these species cannot be mixed.

About 50 % of collected larvae of *A. convexicollis* were damaged by parasitoids. In 2013 adults were captured from 1 June to 5 July, in 2014 from 2 June to 7 July.

A. convexicollis was reported to feed on *Fraxinus excelsior*, *F. ornus*, *F. oxyphylla*, *Ligustrum vulgare*, *Syringa vulgaris*, *Olea europea* (Oleaceae) and on some other trees and shrubs such as *Euonymus*, *Betula*, *Corylus*, *Populus*, *Salix*, *Quercus*, *Acer*, *Tilia*, *Ulmus*, and *Cornus* (reviews: Hellrigl 1978; Brechtel and Kostenbader 2002; Bílý 2002). However, most cited authors regard the last several host records to be doubtful. All specimens we collected in central European Russia were collected on *F. pennsylvanica*. This ash species was introduced from North America to European Russia more than 100 years ago and has become one of the most common trees planted in urban settings in central European Russia (Majorov et al. 2012). Our analysis has revealed that before 2007, *A. convexicollis* was not recorded in the central regions of European Russia. The northernmost localities of this species in Russia were in Voronezh region. But since 2007, *A. convexicollis* was found to be established in seven localities of central European Russia: Moscow region, Yaroslavl region and Lipetsk region (Vlasov 2010; Nikitsky 2009; original data). Currently, the northernmost locality is in the Yaroslavl region, i.e. 665 km to the north of the previously known northernmost localities.

Could *A. convexicollis* occur but remain unnoticed in central European Russia before? It is very unlikely, though it is impossible to prove the absence of any insect species in any territory. Fauna of xylophagous beetles in Moscow region has historically been intensively surveyed, but *A. convexicollis* was not recorded (Nikitsky et al. 1996). There are no specimens of *A. convexicollis* collected in central Russia in rich collections of Zoological Institute (Russian Academy of Sciences) and Zoological Museum of Moscow State University, though there are many specimens of other *Agrilus* species collected in this territory. *A. convexicollis* is easy to notice, because it is not microscopic (the length is about 3.5–5.5 mm) and not nocturnal. It occurs on the leaves of ashes in cities, where many professional and amateur entomologists live. Forty-six species of the genus *Agrilus* are known from European Russua (Volkovitsh 2013), but they mainly occur in the south. 17 species are known from Moscow region (Nikitsky et al. 1996, 2013).

Fraxinus excelsior is native, but very rare in Moscow region. Nearly all ash trees are introduced as landscape plants. *F. pennsylvanica* has been planted in central Russia for 50–100 years (Majorov et al. 2012), but *A. convexicollis* appeared only several years ago. We suspect that *A. convexicollis* has only recently expanded its range to the north.

What factors could facilitate such quick expansion? It is well known that many beetles in Europe are now spreading northward because of warming climates (Beenen and Roques 2010). Climate change alone, however, is likely not the only factor to contribute to the northward expansion of *A. convexicollis.* Novel localities of *A. convexicollis* in central European Russia are all dispersed throughout the region recently invaded by emerald ash borer, *A. planipennis*, and most of the specimens have been collected from *A. planipennis*-infested ash trees. Therefore, we suspect that naturalization and expansion of *A. convexicollis* in this region has been facilitated by widespread weakening and mortality of ash trees caused by the emerald ash borer invasion (Fig. 2).

Table 1 Regions and localities where *A. convexicollis* has been found within its native range

Region	Number of mapped localities	Years of collection	Source of information
Albania	0	Pre 2000	Sakalian (2000)
Armenia	1	1955	Examined specimens
Austria	16	1849–1958	Geiser (2001), Jendek (2002), GBIF (2013) and examined specimens
Azerbaijan	1	1912, 1959	Babadjanides (1917), Alexeev (1959)
Belarus	0	Pre 2006	Jendek (2006)
Belgium	15	1860–1998	Schaefer (1949), GBIF (2013)
Bosnia and Herzegovina	0	1978	Popo (1978)
Bulgaria	25	1933–2003	Obenberger (1935), Bílý (1979), Weidlich (1989), Sakalian (2003), GBIF (2013)
Croatia	9	Pre 1994	Curletti (1994), Muskovits and Hegyessy (2002)
Czech Republic	4	1931–2012	Gottwald (1968), GBIF (2013) and examined specimens
France	50	1949–1994	Schaefer (1949), Curletti (1994), Brechtel and Kostenbader (2002), Petitprêtre and Marengo (2011)
Georgia	1	1959–2013	Alexeev (1959) and examined specimens
Germany	54	1934–2004	Weidlich (1987), Köhler and Klausnitzer (1998), Brechtel and Kostenbader (2002), Niehuis (2004), GBIF (2013) and examined specimens
Greece	11	Pre 2000	Mühle et al. (2000)
Hungary	71	Pre 2002	Muskovits and Hegyessy (2002)
Italy	86	1927–2006	Hellrigl (1974), Magnani and Sparacio (1985), Curletti (1994), Jendek (2002), Rastelli et al. (2003), GBIF (2013)
Latvia	1	1900–1993	Barševskis and Savenkov (2001) and examined specimens
Liechtenstein	0	Pre 2006	Jendek (2006)
Luxembourg	0	Pre 2006	Jendek (2006)
Macedonia	1	Pre 2012	GBIF (2013)
Moldova	1	1917	Bacal et al. (2013) and personal communication by N. Munteanu
Montenegro	2	1971, 1977	Drovenik and Hladil (1984) and examined specimens
Poland	20	1887–2006	GBIF (2013), Coleoptera Poloniae (2013)
Romania	5	1940–2002	Muskovits and Hegyessy (2002), Ruicănescu (2013)
Russia, Adygea	1	1880	Volkovitsh et al. (2010) and examined specimens
Russia, Dagestan	1	2013	Examined specimens
Russia, Karachay-Cherkessia	1	Pre 2008	Nikitsky et al. (2008)
Russia, Krasnodar territory	1	1959, 1971, 1978	Alexeev (1959) and examined specimens
Russia, Rostov region	2	1933, 2007	Examined specimens and personal communication by D.V. Vlasov
Russia, Stavropol territory	1	Pre 1935	Jendek (2007)
Russia, Volgograd region	0	Pre 1957	Alexeev (1957)
Russia, Voronezh region	2	1935, 1955	Stark (1955) and examined specimens
Serbia	2	1958	Sakalian et al. (2001), GBIF (2013)
Slovakia	10	1947–2002	Gottwald (1968), Bozděchová (1971), Muskovits and Hegyessy (2002), GBIF (2013)
Slovenia	1	Pre 1994	Curletti (1994)
Spain	1	Pre 2005	Verdugo (2005)
Sweden	17	1949–2009	Bílý (1982), GBIF (2013)

Table 1 continued

Region	Number of mapped localities	Years of collection	Source of information
Switzerland	30	1886–2007	Schaefer (1949), CSCF (2013)
Turkey	5	1972–1976	Niehuis and Tezcan (1993)
Ukraine	23	1907–2008	Alexeev (1959), Zagajkevich (1962), IUCN Evaluation Report (2007), Prokhorov (2010) and examined specimens

Specimens examined are primarily deposited in the collections housed at the Zoological Institute of the Russian Academy of Sciences, St. Petersburg

Table 2 Localities where *A. convexicollis* has recently been found in central European Russia

Collection localities	Number of locality in the map	Coordinates	Dates	Number of specimens	Was the tree damaged by *A. planipennis*?	Source of information
Yaroslavl region						
Yaroslavl	1	57.63N, 39.87E	2007 and 30.6.2013	4 adults	Yes	Examined specimens and Vlasov (2010)
Moscow region						
Zelenograd	2	55.99N, 37.20E	1.6.2013–29.6.2014	51 adults, 12 larvae	Yes	Examined specimens
Manikhino	3	55.88N, 36.97E	15.6.2008	1 adult	Yes	Nikitsky (2009)
Staraya Kupavna	4	55.81N, 38.18E	21.6.2013	9 adults	Yes	Examined specimens
Monino	5	55.84N, 38.20E	21.6.2013	2 adults	Yes	Examined specimens
Uzunovo	6	54.55N, 38.62E	29.6.2013	1 adult	Yes	Examined specimen
Lipetsk region						
Gryazi*	7	52.49N, 39.93E	27.6.2013	1 adult	No	Examined specimen

Examined specimens were collected on *Fraxinus pennsylvanica.* All specimens but one were collected from ash trees known to be infested by emerald ash borer, *A. planipennis*

* An adult of *A. convexicollis* was captured in Gryazi on the declining *Fraxinus pennsylvanica.* But we did not find signs of infestation by *A. planipennis* there, though this location is between known locations of *A. planipennis.* Gryazi is quite close to the native range of *A. convexicollis*. So it is unknown, if this location is a part of native or secondary range

The emerald ash borer, *A. planipennis* is an invasive ash pest in North America and Europe (Cappaert et al. 2005; EPPO 2013). Its native range is East Asia (Jendek 2006; Jendek and Grebennikov 2011). The first introduction of this Asian pest in Europe was recorded in 2003 in Moscow (Shankhiza 2007; Volkovitsh 2007). Since then, *A. planipennis* has been detected in 11 regions of European Russia (Orlova-Bienkowskaja 2013a, b; Baranchikov 2013; Straw et al. 2013; Volkovitsh and Mozolevskaya 2014). All known localities of *A. convexicollis* in central European Russia are within the region currently infested by *A. planipennis* (Fig. 2). Furthermore, all specimens of *A. convexicollis* except one were collected on declining *F. pennsylvanica* infested with *A. planipennis. Fraxinus pennsylvanica* is a new host record for *A. convexicollis.* Larvae and young beetles of *A. convexicollis* were collected from under the bark of the upper parts of the stems, which were already dry. As *A. convexicollis* can feed on this American ash species, it theoretically could become a pest in the case of invasion to North America, but it is unknown, whether this species is able to damage healthy trees.

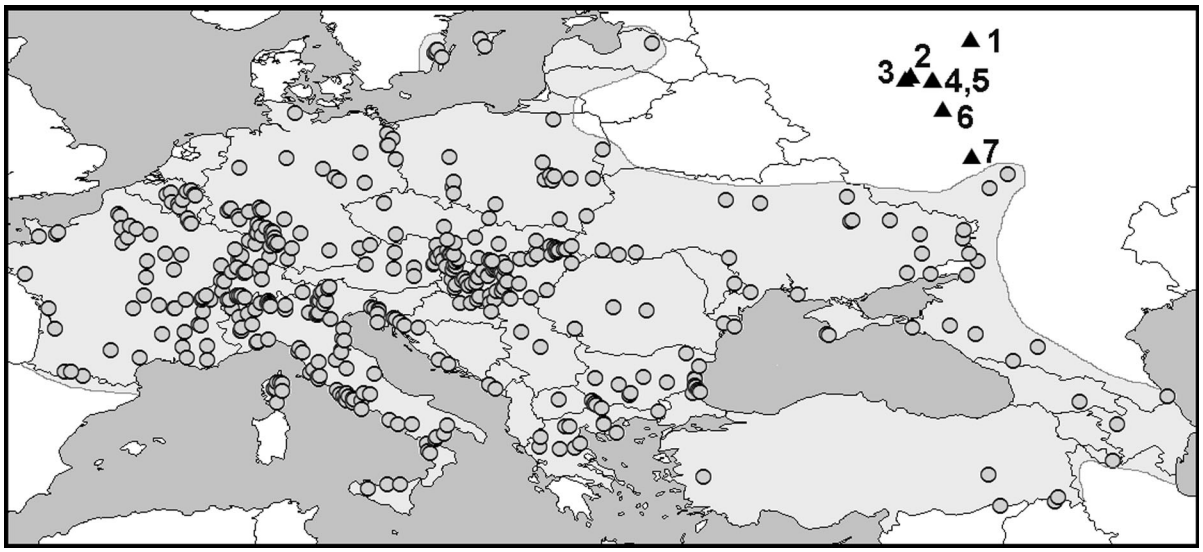

Fig. 1 The known range of *A. convexicollis* as of 2013. *Circles*—findings within native range. *Triangles*—recent findings in central European Russia (2007–2013). The range before 2007 is *shaded gray*. *Numbers* of localities correspond to the numbers in Table 2. Sources of information are listed in Tables 1 and 2

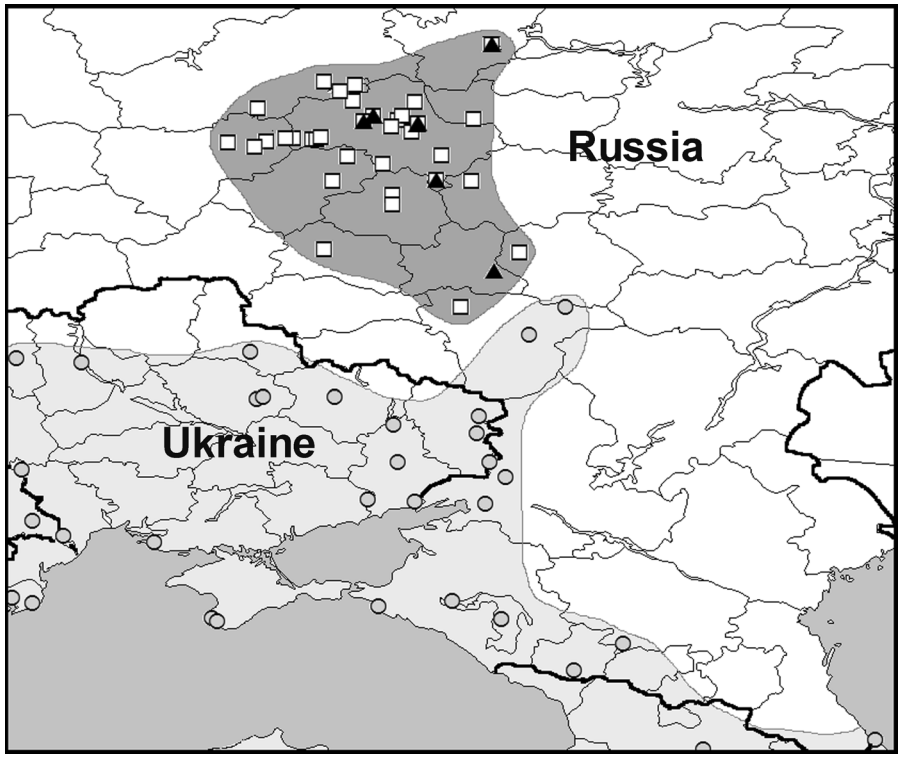

Fig. 2 The known ranges of *A. convexicollis* and *A. planipennis* in European Russia and adjacent regions as of 2013. *Dark gray area*—invasive range of *A. planipennis*. *Squares*—localities, where *A. planipennis* was found. *Light gray area*—native range of *A. convexicollis*. *Circles*—localities, where *A. convexicollis* was found within its native range. *Triangles*—localities where *A. convexicollis* was found outside its native range (all findings in 2007–2013). Range of *A. planipennis* is given after Orlova-Bienkowskaja (2013b)

The spread of *A. planipennis* in central European Russia has caused mass weakening and mortality of ash trees, which, in turn, creates an ephemeral host resource suitable for *A. convexicollis* colonization. The quickly increasing amount of larval food now available to *A. convexicollis* has likely facilitated its

population buildup and spread northward. Biological invasions often have cascading ecological effects, including secondary invasions by other species (Simberloff and Von Holle 1999; Simberloff 2006). This work illustrates how the invasion of one species may facilitate the range expansion of another species.

Acknowledgments We would like to thank Eduard Jendek (Ottawa Plant Laboratory, Canadian Food Inspection Agency, Ottawa, Ontario, Canada) for the data on the European localities of *A. convexicollis;* we are also grateful to Vítězslav Kubàň (National Museum, Prague, Czech Republic), Dmitrij Viktorovich Vlasov (Yaroslavl State Historical-Architectural and Art Museum-Reserve, Yaroslavl, Russia) and Natalia Munteanu (Institute of Zoology, Academy of Sciences of Moldova) for valuable information, and to Nathan W. Siegert (USDA Forest Service) for linguistic corrections.

References

Alexeev AV (1957) The buprestid-beetles of Stalingrad province (Coleoptera, Buprestidae). Uchenye zapiski Orekhovo-Zuevskogo Pedagogicheskogo Instituta 10:115–158 (in Russian)

Alexeev AV (1959) A key for identification of buprestid-beetles of the genus *Agrilus* Curtis of European part of the USSR (Coleoptera, Buprestidae). In: Orekhovo-Zuevskii Pedagogicheskii Institut (ed) Sbornik rabot po ekologii i sistematike zhivotnykh. Orekhovo-Zuevskii Pedagogicheskii Institut, Moscow, pp 3–25 (in Russian)

Alexeev AV (1981) A key to determination of the larvae of buprestid beetles of the genus *Agrilus* Curtis (Coleoptera, Buprestidae) of European part of the USSR. Sbornik trudov zoologicheskovo muzeya MGU 19:65–84 (in Russian)

Babadjanides J (1917) Liste des Buprestides trouvés dans environs d'Elisavetpol. Izvestiya Kavkazskogo Muzeya 10:321–324 (in Russian)

Bacal S, Munteanu N, Toderas I (2013) Checklist of beetles (Insecta: Coleoptera) of the Republic of Moldova. Brvkenthal Acra Mvsei 8(3):415–450

Baranchikov YN (2013) EAB is the main acronym in European forest protection in the first half of this century. In: Selikhovkin AV, Musolin DL (eds) Proceedings of the The Kataev Memorial Readings—VII. Pests and Disease of Woody Plants in Russia, Saint Petersburg State Forest Technical University, pp 8–9

Barševskis A, Savenkov N (2001) Materials on Latvian Buprestidae (Coleoptera) fauna. Latv Entomol 38:4–12

Beenen R, Roques A (2010) Leaf and seed beetles (Coleoptera, Chrysomelidae), Chapter 8.3. In: Roques A et al. (eds) Alien terrestrial arthropods of Europe. BioRisk. doi:10.3897/biorisk.4.52

Bílý S (1979) New records and rare species of buprestids from Bulgaria (Coleoptera, Buprestidae). Acta Zool Bulg 13:47–52

Bílý S (1982) The Buprestidae of Fennoscandia and Denmark. Fauna Entomol Scand 10:1–110

Bílý S (1999) Larvae of buprestid beetles (Coleoptera: Buprestidae) of Central Europe. Acta Entomol Mus Natl Pragae Suppl 9:1–45

Bílý S (2002) Summary of the bionomy of the Buprestid beetles of Central Europe (Coleoptera: Buprestidae). Acta Entomol Mus Natl Pragae Suppl 10:1–104

Bozděchová J (1971) Krasci (Col., Buprestidae) ve sbírkách zoologického oddělení Západočeského Muzea. Zprávy Muzeí Západočeského Kraje 12, Příroda (Plzeň): 13–20

Brechtel F, Kostenbader H (eds) (2002) Die Pracht-und Hirschkäfer Baden-Württembergs. E. Ulmer, Stuttgart

Cappaert D, McCullough DG, Poland TM, Siegert NW (2005) Emerald ash borer in North America: a research and regulatory challenge. Am Entomol 51:152–165

Coleoptera Poloniae (2013). http://coleoptera.ksib.pl/search.php?l=en. Accessed 14 Nov 2013

CSCF (2013) Centre Suisse de Cartographie de la Faune. (http://lepus.unine.ch/carto/index.php?nuesp=21364&rivieres=on&lacs=on&hillsh=on&year=1990). Accessed 14 Dec 2013

Curletti G (1994) I Buprestidi d'Italia. Catalogo tassonomico, sinonimico, biologico, geonemico. Natura Bresciana, Brescia, Monografie N° 19

Drovenik B, Hladil J (1984) A contribution to the knowledge of the Buprestidae (Coleoptera) of Yugoslavia. Biol Vestn 32(1):7–18

EPPO (2013) European and mediterranean plant protection organization. Database on quarantine pests. http://www.eppo.int/DATABASES/pqr/pqr.htm. Accessed 20 Sept 2013

GBIF (2013) Global biodiversity information facility: ArtDatabanken, IFR-DNF, LI, LMD, RBINS, TAMU, ZSM. http://www.gbif.org/. Accessed 14 Nov 2013

Geiser E (2001) Die Käfer des Landes Salzburg. Faunistische Bestandserfassung und tiergeographische Interpretation. Monographs on Coleoptera Wien. 2. NHMW, Wien

Gottwald J (1968) Příspěvek k systematice a faunistice krasců Československa (Col., Buprestidae). Acta Entomol Bohemoslovaca 65:325–329

Hellrigl KG (1974) Die Prachtkäfer (Col. Buprest.) Südtirols. Koleopterol Rundsch 51:56–79

Hellrigl KG (1978) Ökologie und Brutpflanzen europäischer Prachtkäfer (Col., Buprestidae). Teil 2. Z Angew Entomol 85(3):253–275

IUCN Evaluation Report (2007). http://www.wolf.sk/files/dokumenty/Unesco%20lesy/UNESCO_nomination_project.pdf. Accessed 14 Nov 2013

Jendek E (2002) Nomenclatural and taxonomic notes on *Agrilus cyanescens* (Ratzeburg, 1837), *A. pratensis* (Ratzeburg, 1837) and *A. convexicollis* Redtenbacher, 1849 (Coleoptera: Buprestidae: Agrilinae). Zootaxa 77:1–11

Jendek E (2006) New nomenclatorial and taxonomic acts, and comments. Buprestidae: *Agrilus*. p. 60. Catalogue. Buprestidae: Agrilinae: Agrilini: Agrilina: *Agrilus*. In: Löbl I, Smetana A (eds) Catalogue of Palaearctic Coleoptera. 3. Scarabaeoidea–Scirtoidea–Dascilloidea–Buprestoidea–Byrrhoidea. Apollo Books, Stenstrup, pp 388–403

Jendek E (2007) Taxonomic and nomenclatural clarifications of the genus *Agrilus* (Coleoptera: Buprestidae: Agrilinae). Entomol Probl 37(1–2):87–95

Jendek E, Grebennikov V (2011) *Agrilus* (Coleoptera, Buprestidae) of East Asia. Jan Farkač, Prague

Köhler F, Klausnitzer B (1998) Verzeichnis der Käfer Deutschlands. Entomolog Nachr und Ber (Dresden). Beiheft 4:1–185

Magnani G, Sparacio I (1985) Nuovi dati geonemici e biologici su alcuni Buprestidi di Sicilia. In: Atti del XIV (eds) Congresso Nazionale Italiano di Entomologia, Palermo, Erice, Bagheria, pp 103–109

Majorov SR, Bochkin VD, Nasimovich YA, Shcherbakov AV (2012) Alien flora of Moscow and Moscow region. KMK Publishing house, Moscow

Mühle H, Brandl P, Niehuis M (2000) Catalogus Faunae Graeciae. Coleoptera: Buprestidae. Selbstverlag, Augsburg

Muskovits J, Hegyessy G (2002) Magyarország díszbogarai (Coleoptera: Buprestidae). Jewel beetles of Hungary (Coleoptera: Buprestidae). Grafon Kiadó, Nagykovácsi

Niehuis M (2004) Die Prachtkäfer in Rheinland-Pfalz und im Saarland. Beiheft 31 der Schriftenreihe "Fauna und Flora in Rheinland-Pfalz". Gesellschaft für Naturschutz und Ornithologie Rheinland-Pfalze, V. Mainz

Niehuis M, Tezcan S (1993) Beitrag zur Kenntnis der *Agrilus*-Arten der Türkei (Coleoptera: Buprestidae). Mitteilungen des Internationalen Entomologischen Vereins 18(1–2): 1–74

Nikitsky NB (2009) New and interesting finds of xylophilous and some other beetles (Coleoptera) in the Moscow Region and in Moscow. Bull Soc Nat Mosc 114(5):50–58 (in Russian)

Nikitsky NB, Osipov IN, Chemeris MV, Semenov VB, Gusakov AA (1996) Coleptera: xylobionts, mycetobionts, and scarab beetles of The Prioksko-Terrasny Nature Biosphere Reserve. Archives of Zoological Museum of Moscow State University, 36. Moscow State University, Moscow

Nikitsky NB, Bibin AR, Dolgin MM (2008) Xylophilous beetles (Coleoptera) of the Caucasian State Biospheric Natural Reserve and adjacent territories. Rosskiiskaya akademiya nauk, Syktyvkar (in Russian)

Nikitsky NB, Petrov PN, Prokin AA (2013) New and some others interesting beetles (Coleoptera) of Moscow Region (Russia). Cauc Entomol Bull 9(2):223–241

Obenberger J (1935) Catalogue raisonné des Buprestides de Bulgarie. III Partie. Bulletin des Institutions Royales d'Histoire Naturelle, Sofia 8:23–96

Orlova-Bienkowskaja MJ (2013a) Ashes in Europe are in danger: the invasive range of *Agrilus planipennis* in European Russia is expanding. Biol Invasions. doi:10.1007/s10530-013-0579-8

Orlova-Bienkowskaja MJ (2013b) Dramatic expansion of the range of the invasive ash pest, buprestid beetle *Agrilus planipennis* Fairmaire, 1888 (Coleoptera, Buprestidae) in European Russia. Entomolog Rev. doi:10.1134/S0013873813090042

Petitprêtre J, Marengo V (2011) Coleopteres de Rhöne-Alpes Buprestides. Musee des Confluences. Société Linnéenne de Lyon, Lyon

Popo A (1978) Faunistička monografija Buprestidae SR Bosne i Hercegovine (Coleoptera, Sternoxia). Glasnik Zemaljskog muzeja, Sarajevo, Prirodne nauke. N. S. 17:249–292

Prokhorov AV (2010) Annotated list of buprestid beetles (Coleoptera: Buprestidae) of the wood-and-steppe zones of Ukraine. Ukrainska Entomofaunystica 1(4):1–72 (in Russian)

Rastelli M, Curletti G, Barbero E (2003) Note sulla coleotterofauna xilophaga di un bosco di pianura rinaturalizzato: il Gerbasso, Carmagnola (TO) (Coleoptera: Buprestidae, Cerambycidae, Scolytidae). G Ital Entomol 10:217–236

Ruicănescu A (2013) The jewel beetles of Romania (Coleoptera: Buprestidae). Pensoft, Sofia-Moscow

Sakalian VP (2000) Contribution to the knowledge of the jewel beetles of Albania (Coleoptera: Buprestidae). Beitr Entomol 50(1):91–101

Sakalian VP (2003) A Catalogue of the Jewel Beetles of Bulgaria (Coleoptera, Buprestidae). Zoocartographia Balcanica 2. Pensoft, Sofia-Moscow

Sakalian VP, Brajković MM, Mihajlova B, Ćurčić BPM (2001) Contribution to the knowledge of the buprestid beetles (Buprestidae, Coleopterae) from Serbia. Arch Biol Sci Belgrade 53(3–4):45–46

Schaefer L (1949) Les Buprestides de France. Tableaux analytiques des Coléoptères de la faune franco-rhénane. France, Rhénane, Belgique, Hollande, Valais, Corse. Famille LVI. Miscellanea Entomologica, Suppl.:1–511

Shankhiza EV (2007) Invasion of the emerald ash borer *Agrilus planipennis* to Moscow region. http://www.zin.ru/Animalia/Coleoptera/rus/fraxxx.htm. Accessed 24 May 2013 (in Russian)

Simberloff D (2006) Invasional meltdown 6 years later: important phenomenon, unfortunate metaphor, or both? Ecol Lett. doi:10.1111/j.1461-0248.2006.00939.x

Simberloff D, Von Holle B (1999) Positive interactions of nonindigenous species: invasional meltdown? Biol Invasions 1:21–32

Stark VN (1955) Retardation in the development of wood-eating species of insects and its significance for the determination of the age composition and terms of emergence of the population. Zool Zhurnal 34(4):775–788 (in Russian)

Straw NA, Williams DT, Kulinich O, Gninenko YI (2013) Distribution, impact and rate of spread of emerald ash borer *Agrilus planipennis* (Coleoptera: Buprestidae) in the Moscow region of Russia. Forestry. doi:10.1093/forestry/cpt031

Verdugo A (2005) Fauna de Buprestidae de la Península Ibérica y Baleares. Argania editio, Entomopraxis, Barcelona

Vlasov DV (2010) Xylophilous beetles, pests of green plantations of Yaroslavl. In: Proceedings of IV interregional Scientific and Practical conference "Ecology and culture: from the past to the future" Indigo, Yaroslavl, pp 156–162

Volkovitsh MG (2007) Buprestid beetle *Agrilus planipennis* a new dangerous pest of ashes in European part of Russia. http://www.zin.ru/Animalia/Coleoptera/rus/eab_2007.htm. Accessed 4 July 2014 (in Russian)

Volkovitsh MG (2013) Annotated list of buprestid beetles (Buprestidae) of Russia http://www.zin.ru/Animalia/Coleoptera/rus/bupcatru.htm. Accessed 4 July 2014 (in Russian)

Volkovitsh MG, Mozolevskaya EG (2014) The tenth "anniversary" of the invasion of Emerald Ash Borer *Agrilus planipennis* Fairm. (Coleoptera: Buprestidae) in Russia—results and prospects. Izvestia Sankt-Peterburgskoj lesotehniceskoj akademii (in Russian) (in press)

Volkovitsh MG, Nikitsky NB, Bibin AR (2010) Family Buprestidae—Jewel Beetles. In: Zamotajlov AS, Nikitsky NB (eds) Coleopterous insects (Insecta, Coleoptera) of Republic of Adygheya (annotated catalogue of species) (Fauna conspecta of Adygheya. No 1). Adyghei State University Publishers, Maykop, pp 117–126 (in Russian)

Weidlich M (1987) Lepidopterologische und coleopterologische Beobachtungen aus den mittleren und nördlichen Teilen des Bezirkes Halle/S. unter besonderer Berücksichtigung von Gefährdungsursachen (Insecta, Macrolepidoptera, Coleoptera: Buprestidae et Cerambycidae). Faunist Abh Staat Mus für Tierkd Dresden 14(9):131–160

Weidlich M (1989) Faunistik und Imaginalökologie der Prachtkäfer Bulgarisch-Mazedoniens (Insecta, Coleoptera: Buprestidae). Faunist Abh Staat Mus für Tierkd Dresden 17(7):47–77

Zagajkevich IK (1962) Geographical distribution and biology of jewel beetles of the genus *Agrilus* Curt. in Ukraine. Naukovi Zapisky Naukovo-prirodoznavchogo muzeyu AN URSR, Kiev 10:101–111 (in Ukrainian)