First record of the invasive alien species *Cynaeus angustus* (LeConte, 1851) (Coleoptera, Tenebrionidae) in Bulgaria

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Abstract: The invasive alien species *Cynaeus angustus* (LeConte, 1851) was detected for the first time in Bulgaria. In 2020–2022, eight exemplars of this North American pest were collected at three sites along the Danube River. Its distribution, microhabitat affinity, food preferences as well as some methods for control are outlined. Photographs of the adult habitus, male genitalia and female ovipositor are also provided.

Keywords: adventive species, larger black flour beetle, stored grain pest

Introduction

Globalisation facilitates and intensifies the spread of invasive alien species through intentional or accidental introductions (Meyerson & Mooney, 2007). Europe is highly exposed to insect introductions through agricultural trade, and currently around 33% of the invasive insects in the continent are considered alien species of American origin (Bacon et al., 2012). Additionally, it was established that coleopterans dominate among the group of introduced terrestrial invertebrates (Denux & Zagatti, 2010).

*Cynaeus angustus* (LeConte, 1851), also known as the larger black flour beetle, is a Nearctic species native to Southwestern United States and Mexico, specifically the Sonoran-Chihuahuan deserts (Barak et al., 1981; Dunkel et al., 1982). It was originally described by LeConte (1851–1852) as *Platydema angustum* from California (USA), while the description of its larva and pupa was provided by Spilman (1984). This detritivorous insect (Denux & Zagatti, 2010) and a well-known North American pest has considerably extended its range in the past few decades, most probably due to international trade.

In North America the larger black flour beetle is associated with the following natural host plants: *Carnegiea gigantea* (Engelm.) Britton & Rose (Hubbard, 1899), *Agave parryi* Engelm., *Yucca brevifolia* Engelm., *Hesperoyucca whipplei* (Torr.) Trel., *Fouquieria columnaris* (Kellogg) Kellogg ex Curran, *Adenostoma fasciculatum* Hook. & Arn., *Ficus* sp., *Pinus banksiana* Lamb., *Populus tremuloides* Michx. (Dunkel et al., 1982), *Ferocactus wislizeni* (Engelm.) Britton & Rose (Ferro et al., 2013) and *Dasylirion wheeleri* S. Watson ex Rothr. (GBIF, 2022). Other natural microhabitats such as bird and insect nests (e.g. nests of *Passer domesticus* (Linnaeus, 1758), *Bombus pensylvanicus* (De Geer, 1773), *Osmia* sp.) were listed less frequently (Dunkel et al., 1982). In Europe it was recorded on *Pinus* sp. (Wikars, 2014; GBIF, 2022); *Populus* sp. (Roosileht, 2015; Kadej et al., 2019; Królik, 2019; Pintilioae & Teodorescu,
2021; UkrBIN, 2022; GBIF, 2022); Ulmus sp. (Kovalenko et al., 2016); Fagus sp. (Ruta et al., 2017); Malus sp. (Kadej et al., 2019); Pleurotus ostreatus (Jacq.) P. Kumm. (Królik, 2019); Betula sp., Tilia sp., Fraxinus excelsior L. and Ceriopus squamosus (Huds.) Quél. (GBIF, 2022).

Hatch (1939, 1940) was the first to report C. angustus infestation in stored products, and shortly afterwards the species become a pest of economic importance in a variety of commodities in the United States (Barak et al., 1981; Dunkel et al., 1982). Ultimately, it has become a successful cosmopolitan pest due to its polyphagous behaviour and broad environmental tolerance (Sinha, 1973). Actually, this insect approaches the same level of destruction as some lepidopteran pests, such as Plodia interpunctella (Hübner, [1813]), causing both energy and economic losses (Barak & Harein, 1981; White & Sinha, 1987).

Infestation typically occurs during the first season of storage and increases over time (Decker, 1941; Barak et al., 1981; Barak & Harein, 1981). The affinity of this pest to stored corn is well-defined, but it has been regularly found in a wide variety of stored products (Krall & Decker, 1946; Dunkel et al., 1982) and some man-made habitats, for instance: wheat, barley, oats, sorghum, rice, soybeans, different types of flour, dried fruits, nuts, tobacco, crops in field, crop residues (e. g. cotton gin trash piles, waste grain, mill waste, cutted grass), potatoes (rotten), pulpwwood, animal feed, poultry houses and other domestic animal areas, dead animals, animal manure, compost, worm beds, farm grain bins, grain elevators, flour mills, greenhouses, peanut warehouses, railroad cars, bakeries, retail stores, mausoleums, human residences, etc. (Hatch, 1940; Krall & Decker, 1946; Barak et al., 1981; Dunkel et al., 1982; Semple, 1986; Dunford & Young, 2004; Reibnitz & Schawaller, 2006; Nansen et al., 2008; Hagstrum et al., 2013; Hong & Yun, 2017; Kadej et al., 2019; Pütz, 2020; GBIF, 2022). Furthermore, larvae are also able to digest a very wide range of foods supported by proteinases from serine, cysteine and aspartic classes (Oppert et al., 2006).

Additionally, the larger black flour beetle is also a facultative fungivore and feed on various seed-borne fungi, but it was demonstrated that larval growth is supported exclusively by Aspergillus candidus Link, A. glaucus (L.) Link and Penicillium citrinum Thom, whereas adults reproduce only on Cladosporium cladosporioides (Fresen.) G. A. de Vries, A. flavus Link, Nigrospora sphaerica (Sacc.) E. W. Mason, Stemphylium botryosum Wallr., Curvularia spicifera (Bainier) Boedijn, Fusarium verticillioides (Sacc.) Nirenberg, Microascus brevicatulis S. P. Abbott, Mucor racemosus Fresen., M. silvaticus Hagem, P. aurantiogriseum Dierckx, Talaromyces funiculosus (Thom) Samson, N. Yilmaz, Frisvad & Seifert and Rhizopus arrhizus A. Fisch. (Sinha, 1971; Wright & Burroughs, 1983).

The life cycle of the beetle usually takes 6–10 weeks but under favourable conditions it can be completed in 4 weeks (Ikin et al., 1999). Adults live for 6–12 months (Ikin et al., 1999) and breed continuously at optimal temperature (~30°C), whereas the estimated fecundity is 360 to 450 eggs per female (Krall & Decker, 1946). Moreover, this species is also capable to withstand rather long periods of inactivity at moderately low temperatures in both larval and adult stages (Krall & Decker, 1946).

Records show that adults are nocturnal and fairly strong fliers (Krall & Decker, 1946; Reibnitz & Schawaller, 2006; Nansen et al., 2008). They are also attracted to light, and being able to disperse over long distances sometimes invade public and private buildings becoming nuisance (Krall & Decker, 1946; Dunkel et al., 1982; Morrison & Dunkel, 1983; Dunford & Young, 2004; Oppert et al., 2006; Nansen et al., 2008; Köhler & Köhler, 2009; Roosileht, 2015; Drogaalenko & Konovalov, 2016; Kovalenko et al., 2016; Eichler & Pütz, 2017; Novák et al., 2019; Hron, 2020; Merkl & Szalóki, 2020; Novák & Ryšánek, 2020; Telnov et al., 2020).

Methods

Material was collected at three different locations along the Danube River in 2020–2022. Two types of light devices were used: a light “tower” with 160W mercury-vapour lamp and portable light traps with 8W actinic tube lamps. Specimens were fixed in a mixture of ethanol, acetic acid and glycerol (a solution formulated by Hood, 1953). Genitalia were extracted, macerated in KOH and stained in chlorozol black. Ovipositor was subsequently inflated with direct injection of absolute ethanol. Above-mentioned structures were mounted in euparal.

Species identification was based on the taxonomic keys and descriptions provided by LeConte (1851–1852, 1861–1862), Horn (1870), LeConte & Horn (1883), Champion (1884–1893), Bradley (1930),
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Habitats were photographed with a Nikon Coolpix P7700. Specimens were photographed with a Canon EOS 1300D DSLR camera attached to a Zeiss Stemi 2000-C microscope. Genitalia were photographed with a Canon EOS 2000D attached to a Zeiss Jena Amplival compound microscope. Different focal planes were stacked with Helicon focus Pro v7.7.4 (Helicon Soft) and edited with Adobe Photoshop 2021 v.22.3.0.

Distribution maps were created using Quantum GIS 3.22.2-Białowieża, ESRI satellite imagery and spatial data provided by geoBoundaries (Runfola et al., 2020).

All collected specimens were deposited in the zoological collection of Sofia University St. Kliment Ohridski, Bulgaria (BFUS).

**Results and discussion**

*Cynaeus angustus* (LeConte, 1851) (Figs 1, 2)

New records. BULGARIA • Western Danubian Plain, southeast of Archar Village, 43.8022°N, 22.9483°E, 80 m alt., 12.X.2020, 1 ♂, BFUS-I-OS001448, at light, O. Sivilov & B. Zlatkov leg.

• Middle Danubian Plain, northeast of Hadzhidimitrovo Village, 43.5365°N, 25.4830°E, 80 m alt., 17.VI.2021, 1 ♂, BFUS-I-OS001893, at light, O. Sivilov, B. Zlatkov & R. Bekchiev leg.

• the same locality, 43.5380°N, 25.4834°E, 115 m alt., 20.VI.2022, 1 ♂, BFUS-I-OS002213, 2 ♀♀, BFUS-I-OS002214, BFUS-I-OS002215, at light, O. Sivilov & B. Zlatkov leg.


The following map (Fig. 3) presents distribution of *Cynaeus angustus* in Bulgaria, while habitats are shown in Fig. 4.

*Cynaeus angustus* is a pest of economic importance in the United States as well as a successful cosmopolitan pest (Sinha, 1973; Barak et al., 1981; Dunkel et al., 1982). In the earliest stage of its range expansion the larger black flour beetle has spread gradually over USA until it reached Canada in the 1940s (Dunkel et al., 1982). Subsequently it invaded some South American countries as well, namely Chile (Legner & Olton, 1970), Colombia (Posada, 1976, 1989; Tróchez, 1987, 1999) and Brazil (Ramos, 2009; Peixoto et al., 2016). The first transoceanic case of C.
*angustus* infestation was detected in 1964 when the pest was found in a shipment of tobacco from Georgia (USA) to Dublin (Ireland) (Aitken, 1975); although, that particular accident did not result in an established introduction (Duff, 2012). Since the early 1990s, the species has been frequently reported in many European countries (Fig. 5): Finland (Mannerkoski & Ferrer, 1992; Ferrer, 1995; Ferrer & Andersson, 2002b; Silfverberg, 2010; GBIF, 2022), Sweden including the island of Gotland (Ferrer, 1995; Lundberg, 1996; Ferrer & Andersson, 2002b; Denux & Zagatti, 2010; Silfverberg, 2010; Wikars, 2014; GBIF, 2022), Germany (Reibnitz & Schawaller, 2006; Kopetz et al., 2008; Kähler & Köhler, 2009; Eichler & Pütz, 2017; Pütz, 2020; GBIF, 2022), France (Callot & Matt, 2006; Soldati, 2007; Soldati & Godiant, 2013), Estonia (Roosileht, 2015; GBIF, 2022), Ukraine (Drovalenko & Konovalov, 2016; Kovalenko et al., 2016; UkrBIN, 2022), European Russia (Kovalenko et al., 2016), Czech Republic (Mantić & Vávra, 2017; Novák et al., 2019; Hron, 2020; Novák & Ryšánek, 2020), Poland (Ruta et al., 2017; Kadej et al., 2019; Królik, 2019; Bunalski et al., 2020), Latvia (Telnov et al., 2020), Hungary (Merkel & Szalóki, 2020) and Romania (Pintilioae & Teodorescu, 2021). The beetle was also reported in the following Asian countries: Thailand (Sukprakarn & Tauthong, 1981), Bangladesh (Hasan, 2000), Japan (Ando & Ebina, 2012; Akita & Yamaji, 2014), China (Haijian et al., 2016; Shengfang et al., 2016), South Korea (Hong & Yun, 2017) and Indonesia (Jhon et al., 2020). However, based on the photographed exemplars, we concluded that the records from Ethiopia (Gongsha & Hiruy, 2020) and Hawaii (USA) (GBIF, 2022) are erroneous.

The larger black flour beetle is considered a quarantine pest in some countries, such as Australia (Ikin et al., 1999), Guatemala (MAGA, 2008), New Zealand (NZG, 2021), Japan (Ando & Ebina, 2012) and Korea (Hong & Yun, 2017). *Cynaeus angustus* is not covered under Regulation No. 8 of 27 February 2015 on phytosanitary control (BMA, 2015), respectively, it is not a regulated plant pest in Bulgaria.
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Fig. 4. Habitats of *Cynaeus angustus* in Bulgaria: A – southeast of Archar Village; B – northeast of Hadzhidimitrovo Village; C – northwest of Garvan Village.
However, its presence in the Danubian Plain will most likely impact the local farmers in the future. In this respect, some authors suggest that *C. angustus* can be controlled by particular enzyme inhibitors as well as certain bioagents, namely *Steinernema carpocapsae* (Weiser, 1955) and *Nosema cynaeae* Krall, 1950 (Krall, 1950; Oppert et al., 2006; Nansen et al., 2013). Ionising radiation sterilisation is also recommended; usually, doses of 0.2 to 0.5 kGy are sufficient for most stored-product insect pests including the larger black flour beetle (Chuaqui-Offermanns, 1987). Ultimately, Negherbon (1959) demonstrated that fumigation with sulfuryl fluoride is the most effective way to control *C. angustus*.

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