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First record of the Black Soldier Fly, *Hermetia illucens,* in the Western regions of France (Vendée, Loire-Atlantique, Ille-et-Vilaine) with notes on its worldwide repartition (Diptera, Stratiomyidae)

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Abstract. – The current animal feed market, using unsustainable and expensive protein sources, is looking for more viable alternatives. Insect farming has been proposed as a good solution for this problem. Allowing a great flexibility in the substrates they are fed, and with and short life cycle, one of the most promising candidates for a large-scale production is the Black Soldier Fly (*Hermetia illucens*). While it appears to be a cosmopolitan species, its presence is attested in France only since 1986. For the first time, we report its presence in Vendée, Loire-Atlantique and Ille-et-Vilaine departments. A literature review is also realised about its worldwide distribution. Recording and mapping the distribution of this commercially important species is essential as the establishment of BSF production facility might be hampered by policy-makers, by the need to have this species included in the local entomofauna.

Résumé. – **Premier recensement de la Mouche-soldat noire, *Hermetia illucens*, dans l'ouest de la France (Vendée, Loire-Atlantique, Ille-et-Vilaine) et commentaires sur sa répartition mondiale (Diptera, Stratiomyidae)**. Le secteur de l'alimentation animale, utilisant des sources de protéines limitées et dont les prix montent, cherche des alternatives viables. L'utilisation des insectes est l'une des solutions envisagées pour pallier ce problème. Autorisant une grande flexibilité de substrat nutritif et ayant un cycle de vie court, l'un des candidats les plus prometteurs pour une production à grande échelle, est la Mouche-soldat noire (*Hermetia illucens*). Tandis qu'elle est considérée comme cosmopolite, sa répartition exacte est très floue et sa présence est attestée en France depuis 1986 seulement. Nous rapportons dans la présente note sa présence dans les départements de Vendée, Loire-Atlantique et Ille-et-Vilaine, ainsi qu'une étude exhaustive sur sa répartition mondiale. Cartographier précisément sa distribution est essentiel car la présence de ce diptère parmi l'entomofaune locale peut être un élément cardinal dans la décision d'implanter — ou non — un site de production de cet insecte régionalement.

Keywords. – New record, Insect as feed, Invasive species.

Price increase and unsustainability of the current animal feed forces feed industry actors to look for potential protein-alternative sources. Consequently, the interest for insect farming is currently growing globally. One of the most promising candidates for large-scale farming is the Black Soldier Fly —BSF— *Hermetia illucens* (Linnaeus, 1758). Its larvae can upcycle low-value organic materials, such as municipal and household wastes, agro-industrials by-products or wastes into nutrient-rich biomass (Lardé, 1990; Newton *et al.*, 2005; St-Hilaire *et al.,* 2007; Hem *et al*., 2008; Diener *et al.*, 2010; Kalová & Borkovcová, 2013).

Among the Hermetiinae (Diptera, Stratiomyidae), the genus *Hermetia* Latreille, 1804, is represented in the Nearctic region by 12 species (James, 1981). *Hermetia illucens* was described in 1758 by the Swedish naturalist Carl von Linné, based on material coming from South-America. This large fly (exceeding 1.5 cm) can be easily recognizable by its infuscated wings and the two large spots on the basal part of its abdomen. While this species seems to be

cosmopolitan, it has been suggested that it has an American origin (ROZKOŠNÝ, 1983). This extremely —temperature and habitat— tolerant animal has a great potential to inhabit new territories at more Northern situations than it has formerly been presumed, therefore it spread rapidly around the globe. However, in order to implement a large-scale production system, it is important for policy makers to ensure that the fly is already present amongst the local entomofauna, to lower the risk of potentially introducing an alien species. Consequently, the exact distribution of *Hermetia illucens* has to be documented.

MATERIAL AND METHODS

All specimens examined in this study were collected using a net. All specimens are deposited in the personal collection of Pierre-Olivier Maquart.

Examined material. – 1 ♂, 2 ♀, France, 85000, La Roche-sur-Yon, centre-ville, boulevard d'Italie, 20.VII.2019, *Maquart P. O. leg*.; 2 ♂, France, 44000, Nantes, bords de l'Erdre, 16.VI.2019, *Maquart P. O. leg*.; 1 ♂, 3 ♀, France, 35380, station biologique de Paimpont, près d'une charogne de rongeur, 2.VI.2011, *Maquart P. O. leg*.

RESULTS AND DISCUSSION

In France, the BSF has been recorded by CHEVIN (1986) in South-Eastern France, followed by DAUPHIN (2003) in the south-west, and then RICHOUX (2009) in the Rhone valley. Picq (*in* RICHOUX, 2009) observed it near Poitiers. To date this was the northernmost published record of this species in France (see fig. 1). Using the INPN website (2019), the species was also observed in the surroundings of Paris. Recently, several specimens were collected in the West coast of France (Vendée and Loire-Atlantique) and in Brittany (Ille-et-Vilaine department), confirming its presence in those regions (see *material examined* section for the exact locations).

On a broader scale, within the Palearctic region, this species can be found between 49°N and 42°N (MARTÌNEZ-SÀNCHEZ *et al.* 2011; ROHÁČEK & HORA, 2013). The species has been introduced to Southern Europe where it was first recorded from Malta in 1926 (LINDNER, 1936) and became widespread after the World War II in the Western part of the Mediterranean subregion. It can now be found in Iberian peninsula (including Canary Islands) (LECLERCQ, 1997; MARTÍNEZ-SÁNCHEZ *et al.*, 2011; FAUNA EUROPEA, 2019), the Eastern Mediterranean (Balkan peninsula —Croatia, Montenegro, Albania— BESCHOVSKI & MANASSIEVA, 1996; SSYMANK & DOCZKAL, 2010; Turkey, ÜSTÜNER *et al.* 2003), Greece (TSAGKARAKIS *et al.*, 2017), Italy (FRANCO, 2013), Switzerland (SAUTER, 1989; TÒTH, 1994) and even Southern Germany (SSYMANK & DOCZKAL, 2010).

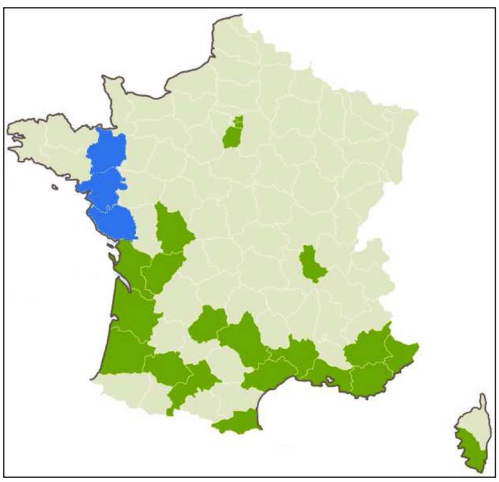

Fig. 1. – Distribution of the Black Soldier Fly *Hermetia illucens* (Linnaeus) in France. Blue: new records, dark green: records according to the INPN website. Modified after www.inpn.mnhn.fr/espece/cd_nom/217341

At the moment, it is accepted that *Hermetia illucens* has an American origin (ROZKOŠNÝ, 1983): it can be found in the tropical regions of South and Central America (COPELLO, 1926; FURMAN *et al.*, 1959; MARSHALL *et al.*, 2015), in USA (for the detailed list of states see MARSHALL *et al.*, 2015) and Canada (Ontario region) (MARSHALL *et al.*, 2015).

Fig. 2. – Worldwide recorded distribution of the Black Soldier Fly *Hermetia illucens* (Linnaeus).

It is also recorded from Asia, such as Koreas —North and South— (Kim, 1997; Kim *et al.*, 2008), Japan (Morimoto & Kiritani, 1995), China, Malaysia and Indonesia (Caruso *et al.*, 2013; Marshall *et al.*, 2015), Sri Lanka (Roháček & Hora, 2013; Caruso *et al.*, 2013), Philippines (Caruso *et al.*, 2013), India (Oliveira *et al.*, 2015). From Oceania: Fidji Islands (Oliveira *et al.*, 2015), New Zealand (May, 1961; McCallan, 1974), Australia (McCallan, 1974), Tahiti (INPN, 2019), Hawaii, Solomon Islands, New Caledonia, Mariana Islands, Palau, Guam (introduced in the 40's during World War II) (Marshall *et al.*, 2015).

There are few documented locations of its presence in Africa. It was officially recorded from La Réunion Island (INPN, 2019), Madagascar (Leclercq, 1997; Oliveira *et al.*, 2015), South Africa (Marshall *et al.*, 2015), Liberia, Ivory Coast, Cameroun, Burundi (Leclercq, 1997), Guinea (Lardé, 1990), Ghana and Mali (Devic & Maquart, 2015). However, its presence can be attested using Facebook, where several BSF-devoted breeding groups share pictures on a daily basis (like "Black Soldier Fly community" and "Black Soldier Fly-BSFL"), where Namibia, Tanzania, Rwanda, Kenya, Uganda, Ethiopia and Senegal can be added to the list. It is therefore expected to be found in all neighbouring countries, and most likely in all tropical and equatorial Africa, at the exception of high altitudes regions.

On a more general basis, the BSF seems to be more frequent along the costal line, suggesting that maritime transport might have played a major role in repeated accidental introductions (Marshall *et al.*, 2015; Martínez-Sánchez *et al.*, 2011).

However, it remains unclear when *Hermetia illucens* firstly arrived in Europe. In 1984, Professor Gino Fornaciari exhumed the body of Isabella d'Aragona (1470-1524) buried in the Abbey of San Domenico Maggiore, in Italy, for paleo-pathological study (D'Errico *et al*., 1988). Fornaciari took this occasion to sample the entomofauna associated to the queen's remains in her sarcophagus. Near Isabella's skull, two body parts belonging to the Black Soldier Fly larva were found. Considering that the fly larvae requires abundant quantities of decaying organic matter (Fornaciari, 2006), and the sarcophagus having been sealed, it is unlikely that the body was contaminated later by the maggots. This finding acknowledged the presence of this fly almost 400 years before the first European record in Malta, suggesting that it was probably present in Italy four centuries before. To this finding, Benelli *et al.* (2014) offer three hypotheses.

– It was introduced from America earlier than we thought: Isabella d'Aragona died the 12th February 1524, almost three decades after the America's discovery by Columbus. At that time, many Spanish galleons were trading in the port of Naples, allowing an accidental introduction.

– The apparent American origin is wrong and it was native from the Palearctic region (even if it remained unknown until 1926).

– The fly larvae do not belong to *H. illucens* but to a new closely related species or a cryptic one. More similar cases have to be found to confirm any one of the three possibilities.

The fly seems to cohabit peacefully with local entomofauna where it has been introduced. Among the Dipteran fauna, its proportion is always very low *in natura*. In Brazil, using household waste as an attractant, a study demonstrated that BSF larvae represented 1% of the total fly population colonising the trap (Ferrari *et al.*, 2009), while in Ghana this ratio was less than 0.2% (Maquart, unpublished). One of the explication could be the competition occurring between BSF and local saprophagous flies: the BSF being very susceptible to competition on its early stages (the first 3-4 days at 30°C), and having a longer development time than most of the other flies, cannot colonize quickly enough a substrate to —later— inhibit the oviposition of other fly species. The presence of Black Soldier Fly larvae is known to inhibit the oviposition of housefly in a substrate (Furman *et al.*, 1959; Bradley & Sheppard, 1984) but only if the substrate is already well colonised. This inhibition is only observed when large density of BSF larvae is present in the substrate, and when the larvae are old enough (*i.e.*: >5 days old at 30°C). Interestingly, this inhibition also occurs on the frass left by the bioconversion.

There is —at the moment— no record of ecological problems due to the introduction of BSF in introduced area, comforting its status of "non-pest" species. Recently, one article published by Hasim *et al.* (2017) allegedly attributed the collapse of wild bee hive colonies to BSF larvae in peninsular Malaysia. However, this very unusual colonisation might have happen because of a drastic change in climate (with an increase of rainfall and humidity due to the entrance to the raining season), and the fact that honey started to ferment, hence potentially attracted female flies to oviposit. The abundance of bee material (rotten propolis, fermented honey and bee bread) becoming a viable substrate for the larvae. This is, to this day, the only recorded case of BSF infestation.

Conclusion

Recording and mapping the distribution of this commercially important species is essential as the establishment of Black Soldier Fly production facility might be constrained by the presence —or not— of this species in the local entomofauna. The potential introduction of an "alien species", following escapes from a nearby facility could be an issue for policy makers, hence the importance of documenting the presence of this species.

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