Hermetia illucens - Black Soldier Fly

Black Soldier Fly (Linnaeus 1758)

Fig. 1. Hermetia illucens (Linnaeus, 1758). Image from Samuel Ewing. Permission obtained and accredited under copyright.

Overview

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The Black Soldier Fly (*Hermetia illucens*) is a cosmopolitan fly belonging to the Stratiomyidae family. It is a relatively large fly with wasp-like appearance. However, unlike wasps, *H. illucens* only possess one pair of wings and lacks a stinger. Moreover, the species exhibits a vast geographical range from America to South-east Asia. *H. illucens* is usually found in outdoor environments near livestock or decaying organic matter, including animal waste. *H. illucens* larvae are widely used in manure management, controlling of housefly populations and the conversion of organic waste into useful products such as compost. The larvae are also sold as important sources of food for reared amphibians and fish as they are high in calcium content. In forensic entomology, the life history and development of *H. illucens* in decaying corpses is used by medico-legal investigators for post-mortem analysis.

**Distribution**

**Locality**

*Hermetia illucens* is a widespread cosmopolitan species found in various parts of the world. The species is hypothesized to originate from tropical, subtropical and temperate zones of America though this is widely contested. It is believed that international transport and commerce in the 20th century led to the introduction of *H. illucens* in other parts of the world. However, others hypothesize that the species is native to Palearctic regions of earth. In Europe, *H. illucens* was first recorded in Malta and has since been discovered and recorded in other parts of Europe and Asia. The widespread distribution of *H. illucens* is shown in the map below:

**Habitat**

*Hermetia illucens* are commonly found resting on garden plants, tree trunks and walls and windows in urban residential areas. The species also inhabit areas with livestock and decaying organic matter.

**Significance of Hermetia illucens**

Environmental importance
Unlike the common housefly, *Hermetia illucens* is not considered a pest as it is not attracted to food or houses. In fact, their larvae play pivotal roles in both environmental and economic aspects of waste disposal and processing. *H. illucens* larvae have been documented to reduce dry manure biomass by 42-56%. Nitrogen concentration and mass were also reduced by 24% and 62% respectively. This drastically reduces the amount of environmental pollutants. Moreover, food processed by larvae averts and dries up organic waste, thereby reducing the production of gases such as methane, an important greenhouse gas. Other odours that may attract pests are also eliminated as the larvae feed on waste.

Feeding by *H. illucens* larvae greatly reduces the production and establishment of a pest housefly, *Musca domestica* L., near decaying organic matter. This occurs as *H. illucens* larvae inhibit the oviposition of *M. domestica* on food waste, possibly by overcrowding their food resource and producing short-lived interspecific chemical signals. *H. illucens* also alters the microflora composition of organic waste, reducing the growth of harmful bacteria such as *Escherichia coli* O157:H7 and *Salmonella* in manure. Consequently, this reduces the spread of disease by reducing bacteria growth and disease vectors such as *M. domestica*.

Vid. 1. Housefly larvae out-competed by *Hermetia illucens* larvae. Obtained from YouTube under fair use

**Economic importance**

Economically, *Hermetia illucens* reduces costs from waste collection and landfills. It is estimated that landfilling is three times more expensive than composting. By reducing the volume of waste by 50%, *H. illucens* drastically decreases the need and costs of landfill. Notably, organic waste composting by *H. illucens* allows for waste recycling and fertilizer production. Harvested *H. illucens* larvae and pre-pupae can be sold as fish feed in various forms (see rearing and breeding in captivity), replacing more expensive conventional fish feed. *H. illucens* has also been used in the production of sugar and biodiesel from dairy manure. It is estimated that manure management using *H. illucens* could increase revenue by $25 000 per year per cage house of livestock. However, research into the industrialization of *H. illucens* is currently ongoing. For example, research on the use of *H. illucens* as a composting agent in campuses is currently conducted in Singapore and America.

*Hermetia illucens* larvae or pre-pupae could be used as high fat and protein feed for fishes as many conventional fish feed lack essential amino acids or have low protein content. Larvae and pre-pupae can be fed live, chopped, frozen or ground. Studies have shown that a diet consisting of *H. illucens* larvae and pre-pupae does not negatively affect fish growth. It may thus serve as a valuable replacement for other expensive sources of fish feed. *H. illucens* larvae was so successful as a feeder insect that it became the first to be registered under a U.S trademark and is now marketed under the brand name "Phoenix Worms". It is also sold under different brands such as "Reptiworms" (Canada) and "Calci Worms".

Should *Hermetia illucens* be unavailable for composting, species such as the yellow soldier fly (*Ptecticus trivittatus*) are also known to degrade organic matter. However, unlike *H. illucens*, *P. trivittatus* prefers rotten fruit which attracts their females to lay eggs.
*P. trivittatus* are usually found in compost along with *H. illucens* and can be distinguished by their smaller size, yellowish colouration, golden thorax and short yellow antennae. Little research has focused on the composting ability of *P. trivittatus* and its usefulness as a composting organism remains unknown.

**Morphology and Identification**

**General anatomy**
Larval and pupae

Larvae of *Hermetia illucens* are dull white in colour with golden-yellow setae and can grow up to 27mm in length. They have a small protruding yellowish-brown head with mouthparts for feeding. *H. illucens* larvae have light yellow ocular prominences on the lateral side of their head while the antennae are low and situated anterolaterally.

As *Hermetia illucens* larvae develop into pupae, they turn dark brown in colour. First instar larvae and pupae of *H. illucens* have not been imaged before. Thus, imaging of key features of *H. illucens* larvae will help to distinguish them from other fly larvae such as *Musca domestica*. Moreover, images could also be used for identification. Mouthparts are also imaged to show morphological differences. Expertise description of larval and pupal images are extremely welcomed.

<p>| First instar larvae | Pupae |</p>
<table>
<thead>
<tr>
<th>Dorsal View</th>
<th>Ventral View</th>
<th>Lateral View</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Fig. 7" /> First instar larvae of Hermetia illucens. Dorsal view. Scale represents 1mm. Image by Jonathan Tan</td>
<td><img src="image2.png" alt="Fig. 9" /> First instar larvae of Hermetia illucens. Ventral view. Scale represents 1mm. Image by Jonathan Tan</td>
<td><img src="image3.png" alt="Fig. 11" /> First instar larvae of Hermetia illucens. Lateral view. Scale represents 1mm. Image by Jonathan Tan</td>
</tr>
<tr>
<td><img src="image4.png" alt="Fig. 8" /> Pupae of Hermetia illucens. Dorsal view. Scale represents 1mm. Image by Jonathan Tan</td>
<td><img src="image5.png" alt="Fig. 10" /> Pupae of Hermetia illucens. Ventral view. Scale represents 1mm. Image by Jonathan Tan</td>
<td><img src="image6.png" alt="Fig. 12" /> Pupae of Hermetia illucens. Lateral view. Scale represents 1mm. Image by Jonathan Tan</td>
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</tbody>
</table>
**Adult characteristics and diagnostic features**

<table>
<thead>
<tr>
<th>Trait</th>
<th>Property</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior-posterior length</td>
<td>- Typically large flies, 15-20mm in length. Black in colour. (Fig. 20)</td>
<td>See <a href="#">General Anatomy</a></td>
</tr>
<tr>
<td>Antennae</td>
<td>- Antennae are elongated and at least twice the length of head in lateral view (Fig. 21)</td>
<td><img src="#" alt="Image of antennae" /></td>
</tr>
</tbody>
</table>

Fig. 13. First instar larvae of Hermetia illucens. View of mouthparts. Scale represents 1mm. Image by Jonathan Tan

Fig. 14. Pupae of Hermetia illucens. View of mouthparts. Scale represents 1mm. Image by Jonathan Tan

Fig. 15. Lateral view of Hermetia illucens head. Circles represent numbered segments of antennae. Note the length of the antennae compared to the head. Image by Jonathan Tan
First two abdominal terga

- Abdomen consisting of 5 visible segments and is black in colour.
- Posterior sides of tergum one and two contain two translucent white oblong spots.
- Last terga has a reddish-brown hue.

Legs

- Legs are black with white tarsi and basal halves of hind tibiae.

Fig. 16. Dorsal view of Hermetia illucens abdomen. Circles represent the translucent patches on abdominal terga 1 and 2 as well as reddish-brown hue of the last abdominal tergum. Image by Jonathan Tan.

Fig. 17. Lateral view of Hermetia illucens legs. Circles represent the white tarsi. Note the whitish portion of the basal half of hind tibia. Image by Jonathan Tan.
Sexual dimorphism

*Hermetia illucens* exhibit various sexually dimorphic traits such as body size, features on the frons and head, abdominal spots and the shape of their abdominal terminalia. The most common way of distinguishing them are the number of whitish hairs on the face and shape of abdominal terminalia.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Female</th>
<th>Male</th>
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<tbody>
<tr>
<td>Face</td>
<td></td>
<td></td>
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<tr>
<td>• Whitish hairs on the face</td>
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Fig. 18. Frontal view of *Hermetia illucens* female. Note the larger number of whitish hairs on the greater and lower parts of the face compared to the male individual. Scale represents 1mm. Image by Jonathan Tan.

Fig. 19. Frontal view of *Hermetia illucens* male. Note that whitish hairs are more sparse on the greater and lower parts of the face. Scale represents 1mm. Image by Jonathan Tan.
- Females have much more white hairs on the faces such that only the four frontal and facial tubercles are dark

Abdominal terminalia

Female:
Femalabdominal terminalia is long. The cerci have two segments and is elongated.

The subgenital plate points distally and is elongated.

**Fig. 20.** Abdominal terminalia of Hermetia illucens female. Scale represents 1mm. Image by Jonathan Tan.

**Fig. 21.** Genitalia of Hermetia illucens male. Scale represents 1mm. Image by Jonathan Tan.
Ongoing.

Genital furca are subtriangular with a big median aperture.

It also possesses broad, leaf-shaped projections.

Male:

- Male
Information are relatively shorter than the female terminalia. The genitalia are proximally emarginate with a synsternum possessing two
Biology

Diet and Feeding

Hermetia illucens larvae feed on a large variety of organic matter, including plant material, decaying animal matter and manure. They are capable of converting large amounts of waste biomass into stored protein (40%) and fat (30%). Hence Hermetia illucens larvae serve as highly proteinaceous animal feed with high energy content. In contrast, H. illucens adults do not feed on solid material but drink liquids. Thus most nutrient stores are accumulated during larval phases, reducing the need for feeding as an adult.

Vid. 2: Time lapse of Hermetia illucens larvae finishing a banana. Obtained from YouTube under fair use.
Mating behaviour and oviposition

Male *Hermetia illucens* exhibit territorial lekking behaviour\(^{41}\). At forest edges, they were observed to be resting on plant leaves and waiting for potential female mates \(^{41}\). Males tend to aggregate in large numbers at particular sites in the wild when mating \(^{41}\). Aggressive behaviour was also reported when other male *H. illucens* invaders entered into the territory of the resting male. This usually occurs in the form of aerial spiralling in which one fly tries to fend off the other \(^{42}\). At the end of this aerial display, the “victor” would return to its original resting place whilst the other leaves \(^{42}\). When a male encounters a passing female, it would fly up towards her and grasp her \(^{41}\).

The pair then descends in copula. Mating activities usually occur in the day when sunlight intensity is high and decreases with diminishing light intensity \(^{52}\). The presence of sunlight was correlated to mating and successful fertilization of *H. illucens* eggs \(^{38}\), \(^{42}\). However, additional research is required to determine the correlation between light wavelengths and mating behaviour.

Once mating has been completed, the female departs in search of oviposition sites. *H. illucens* Females tend to lay their eggs on cracks and crevices such as the flukes of corrugated cardboard near decaying matter \(^{13}\), \(^{42}\), \(^{43}\). Oviposition is affected by temperature and humidity. Females tend to deposit eggs at temperatures higher than 26 °C and at high humidity (60%). 80% of the eggs were deposited when environmental humidity exceeded 60% and this was almost twice the number of eggs laid at lower humidity \(^{42}\).

Development and life cycle
A gravid *Hermetia illucens* female may deposit up to 500 oval-shaped, pale yellow eggs in a single clutch. After four days, larvae will hatch from these eggs. The entire developmental process from birth to adulthood takes approximately 40 days. A typical *H. illucens* larvae stage consists of 6 instars and last for 1422 days during which they feed and accumulate biomass. At the end of the larval stage, *H. illucens* larvae enter the pre-pupal stage. During the pre-pupal stage, *H. illucens* stop feeding and their mouthparts are modified into a climbing appendage (see Larvae and Pupae: Mouthparts). Pre-pupa then migrate away from the larval habitat and organic matter to pupate in a dry habitat using modified pupal mouth appendages. Adults then emerge approximately 14 days later. Pupal time may extend up to a few months and is highly variable. This depends on environmental conditions, particularly temperature and biotic conditions such as larval density and accumulated nutrients. Mating starts 2 days after adults emerge. The average life span of adults is approximately 10 days.
Rearing and breeding in captivity

*Hermetia illucens* are able to process large quantities of organic matter and are consequently important composting organisms as manure and waste management tools. Several substrates such as pig manure, poultry waste, food wastes and various feed meals have been used as raw material for composting. Rearing facilities usually consist of cage layered houses under the animal producing waste. Optimum temperature and humidity ranges are maintained in these facilities to ensure high yield of *H. illucens* larvae production. Temperatures are kept at 29–31 °C and humidity at 50–70%.

Rearing facilities operate by self-collection of *H. illucens* pre-pupae when they migrate away from their habitat into collection bins. This occurs as *H. illucens* larvae climb out of food bins onto a ramp that leads them into a container where they pupate. Collected *H. illucens* pupae are then brought into a greenhouse where they will hatch into adults. The size of screen cages to effectively rear *H. illucens* adults vary. Sheppard et al. (2002) were able to successfully mate *H. illucens* in a 2 by 2 by 4m screen cage housed in a greenhouse. Space is required in order for the aerial mating process to take place. It is also recommended that adult *H. illucens* are kept in greenhouses or exposed to sunlight as sunlight intensity affects mating. Optimal ranges of temperatures and humidity for mating and oviposition are 24–40°C and 30-90% respectively. Recommended minimum light intensity for mating to occur is 63 µmolm2s-1 and optimal light intensity at over 200 µmolm2s-1. Exposure of the cage to sunlight is recommended though artificial lighting has also been shown to work. For successful oviposition, a moist container or corrugated cardboard tray (ie egg-holding tray) should be provided and placed near decaying organic matter which attracts gravid females.

Predation

Not much is known about predators of *Hermetia illucens*. However, animals such as birds, frogs and lizards are known predators of *H. illucens* larvae.

Defensive Adaptation

*Hermetia illucens* are often described as “wasp-like” due to two translucent patches on their second abdominal tergum, allowing them to appear to possess a thin slender, wasp-like waist. *H. illucens* has an elongated antennae and black legs with white tarsi that are also features of wasp-like biomimicry to help deter potential predators.
Conservation status

*Hermetia illucens* is listed as “extant” and does not face the threat of extinction due to their widespread and cosmopolitan distribution.

Taxonomy and Systematics

**Synonyms**

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Listed below are some of the synonyms for *Hermetia illucens* (Linnaeus, 1758) from the Integrated Taxonomic Information System (ITIS):

- *Musca illucens* Linnaeus, 1758
- *Musca leucopa* Linnaeus, 1767
- *Hermetia rufiventris* Fabricius, 1805
- *Hermetia nigricacies* Bigot, 1879
- *Hermetia pellucens* Macquart, 1834
- *Hermetia mucens* Riley & Howard, 1889
- *Hermetia illucens* Copello, 1926
- *Hermetia illucens var. nigritibia* Enderlein, 1914

**Type information**
The holotype for *Hermetia illucens* is in the De Geer collection housed in the Swedish museum of Natural History (Naturhistoriska Riksmuseet, 4).

**Taxonomic classification**

The taxonomic classification shown below is referenced to UniProt Taxonomy (http://www.uniprot.org/taxonomy/343691). The classification reflects ranks of *Hermetia illucens* above the species level and is arranged in descending order from Kingdom to Species level:

- Eukaryota
- Opisthokonta
- Metazoa
- Eumetazoa
- Bilateria
- Protostomia
- Ecdysozoa
- Panarthropoda
- Arthropoda
- Mandibulata
- Pancrustacea
- Hexapoda
- Insecta
- Dicondylia
- Pterygota
- Neoptera
- Endopterygota
- Diptera
- Brachycera
- Stratiomyomorpha
- Stratiomyidae
- Hermetiinae
- Hermetia

**Phylogeny**

The phylogeny of soldier flies has been well-studied using molecular and morphological methods in phylogenetic tree construction. Morphological characters include external and internal morphology of larvae, pupae and adults, such as wings and genitalia. Molecular characters consist of nuclear protein-coding genes, ribosomal DNA (18S and 28S) and complete mitochondrial genomes.

Monophyly of the suborder Brachycera (>100,000 species, 40 families) which contains the family Stratiomyidae of soldier flies is well supported. A comprehensive study of the fly tree of life by Wiegmann et al. (2011) places Stratiomyidae beside sister clades Xylomyidae and Pantophthalamidae, all of which comprise the infraorder Stratiomyomorpha or soldier flies. However, relationships between the various subfamilies of Stratiomyidae are less apparent due to less well-supported monophyly and relationships between certain subfamilies such as Stratiomyinae and Clitellariinae.
Stratiomyidae encompass a family of cosmopolitan flies of suborder Brachycera and infraorder Stratiomyomorpha. The monophyletic family comprises over 2800 species. Monophyly of the subfamily Hermetillae which contains the genus *Hermetia* and species *Hermetia illucens* is well-supported both by morphological and molecular data.
It is hypothesized that the primary terrestrial lineages of the suborder Brachyera, including the infraorder Stratiomyomorpha, diversified in the early Jurassic (160 mya, \(^{54}\)). However, the common ancestor of the Stratiomyidae family originated more recently in a radiation event during the early Cretaceous period (around 129 mya, \(^{52}\)). The major radiation of clades in Stratiomyidae, such as Hermetiinae, is estimated to be around 60-80 mya using molecular data \(^{52}\). The last common ancestor of \(H.\) illucens has been estimated to appear during the early Cenozoic (around 40 mya, \(^{52}\)).
Fig. 32. Chronogram from r8s analysis of both EF-1-alpha and 28S sequences by Brammer & Dohlen (2007). Timescale represents millions of years before their age constrained due to fossil evidence are represented by filled circles with the corresponding age indicated. Branches with high posterior probability (>90%) and bootstrap support (>775%) are bolded. The bracket indicates the Cretaceous period. Sub-family Hermetiinae is highlighted via the red box. Abbreviations of sub-families are as follows: P = Parhadrestiinae, Ch = Chiromyzinae, Pa = Pachygastrinae, B = Beridinae, A = Antissinae, Cl = Clitellariinae, Cr = Chrysoclorininae, H = Hermetiinae, S = Sarginae, St = Stratiomyinae, R = Raphiocerinae.

References

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Contact Me

Jonathan Tan is contactable at jonathan.twt@gmail.com