

An Ethological and Ecological Review of the real-world applications of *H. illucens*

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Manuscript details:	ABSTRACT
<p>Received: 19.07.2017 Accepted: 13.08.2017 Published : 09.09.2017</p> <p>Editor: Dr. Arvind Chavhan</p> <p>Cite this article as: Sammer Marzouk (2017) <i>An Ethological and Ecological Review of the real-world applications of H.illucens; International J. of Life Sciences</i>, 5 (3): 291-296.</p> <p>Copyright: © 2017 Author (s), This is an open access article under the terms of the Creative Commons Attribution-Non-Commercial - No Derivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.</p>	<p>Introduction: The Black Soldier Fly (<i>Hermetia illucens</i>) is a true fly in the family Stratiomyidae and subclass Pterygota. <i>H. illucens</i> has been a topic of interest in the ecological research world for many years. <i>H. illucens</i> possesses special physiological, ethological and ecological features that may allow <i>H. illucens</i> to become a model organism.</p> <p>Results: This literature review looks at the physiological, ethological and ecological features of <i>H. illucens</i>. Existing literature about <i>H. illucens</i> has been searched and analyzed for this paper. From the literature search, it was discovered that <i>H. illucens</i> is not known to have valuable impacts to the world at large. The purpose of doing this review is so that all information available on <i>H. illucens</i> can be chronicled and so the information can be used in real-world applications.</p> <p>Conclusions: It provides a use of <i>H. illucens</i> as a model organism and aims to demonstrate a framework for real-world applications of <i>H. illucens</i>, such as <i>H. illucens</i> becoming a model organism for mosquitoes, Tsetse flies, and house flies.</p> <p>Keywords: Individual Ecology, Population Ecology, Behavioral Ecology, Mating, Ethology, Ecology.</p> <p>INTRODUCTION</p> <p>There are more than 1,000,000 species of Diptera on planet Earth. Most of these species of Diptera are organisms that require little care, take up little space and can be efficiently be raised. The purpose of this literature review is to gather all the available information on <i>H. illucens</i> that is related to raising <i>H. illucens</i> from larvae into adulthood and gathering the most amount of offspring from the adults. Existing literature about <i>H. illucens</i> has been searched and analyzed for this paper. From this information, the idea of <i>H. illucens</i> being used as a model organism is presented. Using <i>H. illucens</i> as a model organism allows the advantage of an easy to take care of, easy to grow organism with evolutionary and biological connections to organisms that present medical and financial problems to specific groups of people.</p>

MATERIALS & METHODS

Obtaining Research Papers

For the literature review, the research papers were obtained from Web of Science. Web of Science is an online database that allows access to thousands of papers. The papers were all allocated to the following topics: *H. illucens*, behavior, sexual dimorphism and ecology. These papers were all copyrighted to the public. There were 26 papers on *H. illucens* and related topics that were chosen for the literature review.

Procedure

For the procedure, the 26 literature reviews were read with the intent and purpose of specifically finding the part of the papers that went along with the information that was to be presented on *H. illucens*. After the specific information was gathered, it was organized into the topics of *H. illucens* which includes behavior, sexual dimorphism, and ecology. After the information was organized, the information was expanded into short paragraph form, which was then combined into the final draft of the paper.

RESULTS

Anatomy/Physiology:

H. illucens has various sexually dimorphic traits such as body size, features on the head, abdominal spots and the shape of their abdominal terminalia to differentiate sex. Females have more whitish hairs on their face. Females only have four black frontal tubercles, and female abdomens are also longer (Rozkosný, 1983). The cerci have two segments (Rozkosný, 1983). The females are also smaller than the males (Rozkosný, 1983). The males have fewer whitish hairs on their face. (Rozkosný, 1983). For males, the genitalia is relatively shorter than the female terminalia (Rozkosný, 1983). The genitalia is in alignment with the syn sternum, possessing two posterolateral lobes on each side (Rozkosný, 1983). As adults, female wing sizes are bigger than the males. Males had an average wing size of 14.24 mm, which females had an average wing size of 14.67mm (Gobbi *et al.*, 2013). As larvae, *H. illucens* can reach 27 mm in length and six mm in width (Rozkosný, 1983). They are a dull, whitish color with a small, projecting head containing chewing mouthparts (Rozkosný, 1983). Larvae pass through six instars and require 14 days to complete development (Rozkosný, 1983). They eat a

lot as larvae as when they are adults they cannot eat, as they lose their mouthparts (Rozkosny, 1983). The energy they gain from being larvae is the energy they have for the rest of their lives (Rozkosný, 1983). *H. illucens* as a pupa is dark brown in colour (Rozkosný, 1983). As adults, *H. illucens* are black. (Rozkosný, 1983). Because of its white tarsi, black legs, and elongated antenna *H. illucens* is a Batesian mimic of the wasp (Rozkosný, 1983). They also have two transparent on their abdomen, allowing them to have a slender, wasp-like abdomen (Rozkosný, 1983). They also have changed their behavior so that they act like wasps. This includes the way they stand, move and flight patterns (Rozkosný, 1983). Adults range from 15 to 20 mm in length (Sheppard *et al.* 2002). They live for about 5-8 days as adults (Newton, 2005).

Ethology:

As larva, the flies have only one purpose and that is to eat (Tomberlin *et al.*, 2013). The reason why is because the energy that they get as a larva is the energy that they will use for the rest of its life (Tomberlin *et al.*, 2002). They move to get their food and only eat as that is their only goal as a larva. After they are ready to pupate, the larvae then move to a new area, preferably dry and cold to go through the transformations (Newton, 2005) When an adult *H. illucens* is territorial, as they follow a lekking system (Tomberlin *et al.* 2001). This is because when it is time to mate, all the males try to find spots in the lekking area (Tomberlin *et al.* 2001). The females only mate with the males who have territory to mate on (Tomberlin *et al.* 2001). Males that do not have any territory do not have anywhere to mate (Tomberlin *et al.* 2001). The more territory a male has, the greater of a chance they have or mating. If another male comes in the area, the two will fight, and the winner will take the territory (Newton, 2005). The most popular territories are the ones that have had the most mating (Tomberlin *et al.* 2001). *H. illucens* are not extremely competitive. Even if another male comes on their land, they are not going to immediately fight them, only if a female is coming will the two engage (Tomberlin *et al.* 2001). Body size does not matter when it comes to mating as females mate with the first male that they see, regardless of size, (Tomberlin *et al.* 2001). Also because *H. illucens* are not competitive, a smaller male can come onto lekking territory, and mate with a female on another male's territory (Tomberlin *et al.* 2001). Direct sunlight encourages mating for *H. illucens*, and it has rarely been recorded mating on

rainy or snowy days (Zhang *et al.*, 2010). Recorded in North America, mating activity begins at 8:00 am, and peaks at 10:00am CDT (Zhang *et al.*, 2010). Oviposition occurs on the 17th day, and has occurred without sunlight, but had a low chance (Tomberlin *et al.* 2001). Females also had mating issues as females with larger wing sizes and larger bodies are more fertile than those with smaller bodies and smaller wings (Gobbi *et al.*, 2013). After mating, females lay their eggs on cracks and crevices near decaying matter (Zhang *et al.*, 2010). As larvae, *H. illucens* feed on the decaying organic material, they were born next to (Dicarlo *et al.* 2010). But as adults, the flies cannot eat, they can only drink water (Tomberlin *et al.*, 2013). This is because their mouth cannot chew (Tomberlin *et al.*, 2013). Towards the end of being a larva, *H. illucens* becomes a puparium (Tomberlin *et al.*, 2013). A puparium is the last larval stage before pupating (Tomberlin *et al.*, 2013). As a puparium, they turn black from releasing melanin, a chemical into their skin that increases the durability of the skin (Tomberlin *et al.*, 2013). They also enter a wandering stage and start to wander (Tomberlin *et al.*, 2013). They “wander” because they are looking for a place to pupate (Tomberlin *et al.*, 2013). This is a preferably a dry and cold place like an underground tunnel, and they also stop eating (Tomberlin *et al.*, 2013). When they find a proper habitat, they stop moving and connect to the ground vertically. (Tomberlin *et al.*, 2013).

Ecology

H. illucens has a range from the Americas to South-Asia (Rozkosný, 1983). They live in areas with lots of decaying matter (Rozkosný, 1983). At all stages, *H. illucens* has a narrow range of temperatures they can live in, between 27-30 degrees Celsius (Rozkosný, 1983). At 36 degrees or higher, they die off. *H. illucens* is not active in winter months, due to the temperature, and because the adults die after breeding, leaving the eggs that will hatch in spring (Tomberlin *et al.*, 2013). Relative humidities of 30–90% were enough for mating, but the higher the humidity, the larger the larvae is. (Holmes *et al.* 2012). As larvae, the *H. illucens* eat decaying organic material, like food scares and kitchen waste (Nguyen *et al.* 2012). But as adults, the flies only drink water (Nguyen *et al.* 2012). In order for *H. illucens* to achieve mating reliability, they must be in a space at least 0.76 by 1.14 by 1.37m or 10 liters (Sheppard *et al.*, 2012). The *H. illucens* habitat is patchily distributed and includes various organic

compositions including animal waste, spoiled fruits and vegetables, fish rendering waste, and carrion (Tomberlin *et al.*, 2013). These habitats can help, or hinder larval development (Tomberlin *et al.*, 2013). This is because of the fish waste and animal waste hinder larval development, and leads to higher mortality rates (Tomberlin *et al.*, 2013). Fruits and vegetables decrease mortality, speed up larval development, and increase overall body size for *H. illucens* as adults (Tomberlin *et al.*, 2013). The main predators of *H. illucens* as both larvae and adults are other Dipterans (Peterson *et al.*, 1960). These include Empididae, Dolichopodidae, Ephydriidae, and Tendipedidae (Peterson *et al.*, 1960). Predators in other genera include Trichoptera, especially species of the genus *Hydropsyche* and Odonata (Peterson *et al.*, 1960). Hymenoptera is a parasitoid that only affects eggs of *H. illucens* (Peterson *et al.*, 1960). Non-insect predators include spiders and leeches which only eat the larvae (Peterson *et al.*, 1960). Frogs are also well-known predators of adult males because males go near bodies of water during mating season (Peterson *et al.*, 1960). *H. illucens* larvae are detritivores and have no real prey (Peterson *et al.*, 1960). Light affects mating because direct sunlight encourages mating for *H. illucens* (Zhang *et al.*, 2010). *H. illucens* has rarely been recorded mating on rainy or snowy days because the light level is too low (Zhang *et al.*, 2010). In a laboratory setting, the level of light with the most amount of mating is 200 $\mu\text{mol}/\text{m}^2$. Insects cannot see infrared or red light (Zhang *et al.*, 2010). The shortest wavelength they can see up to is 700 nm (Zhang *et al.*, 2010). Members of Diptera only have light receptors for high blue or low green colors (480-530 nm) (Zhang *et al.*, 2010). Adult size is determined by pupal development (Gobbi *et al.*, 2013). The more energy the larvae was able to gather, the bigger the adult will be (Gobbi *et al.*, 2013). The amount of food that it receives as a larvae limits its growth. The diet also affects the mass of the flies, which affects fecundity (Gobbi *et al.*, 2013). Females with more mass had more offspring than those with a smaller amount of mass (Gobbi *et al.*, 2013) The temperature and gender of *H. illucens* can factor growth and fitness. At 27 and 30C, females weighed an average of 17-19% more than males (Tomberlin *et al.*, 2009). But males lived 20% longer (Tomberlin *et al.*, 2009). *H. illucens* are “r” selected (Tomberlin *et al.*, 2009). This is because they have about 320-620 eggs in a “big bang reproduction” and die off hours later (Tomberlin *et al.*, 2009). The eggs then grow up with

no parental help (Tomberlin *et al.*, 2009). After the eggs are laid, it takes about 3-4 days for the eggs to hatch (Furman *et al.*, 1959). They stay as larvae for two weeks, and in the pupal stage for two weeks, but this period can increase to four months if resources are limited (Furman *et al.*, 1959). As adults, the flies live for 5-8 days. *H. illucens* live in random distributions (Tomberlin *et al.*, 2002). For larva, this is determined by the amount of supplies, and how they are spaced. In the pupal stage, this is determined by finding an adequate habitat to pupate (Tomberlin *et al.*, 2002). For adults, this is determined by gender, size, and territory (Tomberlin *et al.*, 2002). This is because males and females live in different areas before mating, and those who are larger live in better areas than those who are smaller (Tomberlin *et al.*, 2002). If there is better territory in a close radius, than they flies will be close (Tomberlin *et al.*, 2002). If it is spread out, then the flies will be spread out (Tomberlin *et al.*, 2002). In competition, *H. illucens* as an adult does not have any interspecific competition as they only drink water (Tomberlin *et al.*, 2002). They have intraspecific competition with each other for mating (Tomberlin *et al.*, 2002). Larvae also do not have much interspecific competition (Tomberlin *et al.*, 2002). This is because the larvae are detritivores and do not have competition for dead organic matter in the places that they live in (Tomberlin *et al.*, 2002). The larvae may compete with themselves in intraspecific competition in there are limited resources (Tomberlin *et al.*, 2002). And sometimes, other fly larvae may compete with *H. illucens* larvae for a resource (Tomberlin *et al.*, 2002). *H. illucens* is in a mutualistic relationship with some species of fungi (Brown *et al.*, 1997). This is because *H. illucens* put their eggs on dead fungi, giving them a food source (Brown *et al.*, 1997). When the eggs grow into larvae, they eat the dead fungi, and other species of plants in the area (Brown *et al.*, 1997). This gives the fungi more room to grow. And when the adults die, they make the soil more nutritious for the fungus (Brown *et al.*, 1997). *H. illucens* plays a pivotal role in communities, as they regulate waste disposal (Brown *et al.*, 1997). *H. illucens* helps to keep ecosystems in check because they can keep the nitrogen and phosphorus levels in an ecosystem stable by eating unwanted manure that could damage the cycles (Furman *et al.*, 1959). Also, *H. illucens* keeps pest flies away because they eat the rotting organic matter, leaving the pest flies without a food source (Furman *et al.*, 1959). *H. illucens* also affected by parasitoids, especially Hymenoptera

(Brown *et al.*, 1997). These insects put their offspring in the eggs of Dipterans, and take the nutrients away until the eggs die. After that, the Hymenoptera hatches and leaves (Brown *et al.*, 1997).

DISCUSSION

H. illucens and the knowledge that can be derived from it can be used beyond the implications of just research, to field such as forensics, commercial and medical use, to even recreational gardening. In the field of forensics, *H. illucens* could be used to find the Minimum Postmortem Interval (PMI) of a dead body (Nguyen *et al.* 2013). Since *H. illucens* have their larvae in places with dead organic matter like a human, it could be used with the knowledge of the growth of *H. illucens* larvae in specific temperatures and with specific resources to find the date of death. For example, given a person who was killed on a 26-degree day and they have fruits and vegetables in their stomach, the information gathered about larval development could be used to find when the soldier flies deposit their larvae into the body (Nguyen *et al.* 2013). This time can be used to give a date of when that person was killed and can be used as evidence in a jury to prove or disprove innocence (Nguyen *et al.* 2013). *H. illucens* can also be used to gain cheaper feed for farm animals (Tomberlin *et al.*, 2002). They eat a lot as larvae, and when pupating releases, a chemical called melanin which turns the pupal black (Tomberlin *et al.*, 2002). After it pupates, the vitamin count of a pupal is about that of a soybean, but cheaper and grows at a faster rate (Tomberlin *et al.*, 2002). And it is edible by almost every farm animal (Tomberlin *et al.*, 2002). *H. illucens* as a food can be grown directly at the farm (Newton, 2005) This is because as it eats decomposing organic matter, like animal feces (Newton, 2005). This could save farms money as previously, they would have to import their food from other locations, wasting gas and transportation money (Newton, 2005). It is estimated that *H. illucens* can save a company \$25,000 per year per cage of livestock (Newton *et al.*, 2005). *H. illucens* as larvae is used as food for fish camps, in order to make fish bigger (Kroeckel *et al.*, 2012). This is because as larvae, they have a large amount of calcium which is important for fish development (Kroeckel *et al.*, 2012). This is not often found in a fish's diet and helps fish become bigger (Kroeckel *et al.*, 2012). This brings the advantage of *H. illucens* larvae decreasing the amount of pollution from

manure (Newton, 2005). A problem of this generation is that the phosphorus and nitrogen cycle have been corrupted by the use of artificial means of gaining these chemicals animals, especially cows. Companies make too much manure, and allow it to pile up because they cannot use it for anything else. This allows it to leak into water sources, which contaminates drinking water. *H. illucens* as larvae are unsatisfiable eaters, and if put into manure can decrease the amount by up to 42-64% (Newton, 2005). From the remaining compost, the adults would die on it after giving birth, making it of a higher quality (Newton, 2005). *H. illucens* has also been used in the production of sugar and biodiesel from dairy manure (Li *et al.* 2011). The use of *H. illucens* in farms can make food production safer (Newton, 2005). *H. illucens*, when placed in manure and chicken coups lowered the amount of diseases, most notably *E.Coli* and *Salmonella* in the food (Erickson *et al.* 2014). This is because the larvae alter the chemical composition in mature, making it harder for the diseases to form (Erickson *et al.* 2014). This use of *H. illucens* is a cheap and accessible method that could be used to increase food safety, and save companies money from lawsuits (Erickson *et al.* 2014). In the public world, *H. illucens* has more use than in the field of food and diseases (Newton, 2005). It can be used to discourage other flies from coming to a certain area (Newton, 2005). *H. illucens* can be used to get rid of flies because as larvae it is a ravenous eater and eats fast (Newton, 2005). This leaves little food for other flies (Newton, 2005). Also, the way that it eats, churns its food and leaves it as a liquid (Newton, 2005). This is a state that the other flies cannot eat as larva, which kills the population over time (Newton, 2005). *H. illucens* can also be used in personal gardens (Newton, 2005). They help get rid of pesky insects and diseases in the area. Also, they are great at getting rid of unneeded compost, and make the remaining compost better (Newton, 2005). *H. illucens* also has the potential of becoming a model organism for mosquitoes, houseflies, and Tsetse flies (Aksoy *et al.*, 2014). Tsetse flies spread Malaria and West Nile Disease by sucking the blood of people (Aksoy *et al.*, 2014). *H. illucens* have to get sexual dimorphism that differentiates males and females (Rozkosný, 1983). Mosquitos also have sexual dimorphism. Only female mosquitoes suck blood, the males do not (Aksoy *et al.*, 2014). This limits our focus of this problem. The next thing is that like *H. illucens*, mosquitoes are inactive in winter months due to cold temperatures (Aksoy *et al.*, 2014). And finally, Mosquitos locate mates because of

the sound of the wings flapping (Aksoy *et al.*, 2014). If the females flap their wings louder, they get a mate faster. From *H. illucens*, weaknesses such as the cold weather and having to hear sounds to mate could be used in order to decrease mosquito populations (Aksoy *et al.*, 2014). The could contribute in lowering Malaria rates and stopping Mosquito related diseases across the world. Houseflies can spread typhoid fever and yaws (Aksoy *et al.*, 2014). But like *H. illucens*, they both get advantages from humidity (Aksoy *et al.*, 2014). The higher the humidity, the faster the eggs will grow (Holmes *et al.* 2012). So low humidity areas make it harder for the fly eggs to hatch (Holmes *et al.* 2012). Both *H. illucens* and house flies also have to put their eggs in organic matter so that they can get energy as they get older (Aksoy *et al.*, 2014). If mating areas are removed, then the amount of house flies in an area will decrease (Aksoy *et al.*, 2014). This would help to increase food and water safety, as well as stopping avoidable deaths. The Tsetse fly spreads Sleeping Disease and has 70 million people in Eastern Africa at risk (Aksoy *et al.*, 2014). Studying the fly is difficult because the females only lay one egg at a time at hundreds of locations (Aksoy *et al.*, 2014). The similarity with *H. illucens* and the Tsetse fly is that it has been shown that flies share the same genes that control sex development (Aksoy *et al.*, 2014). This means that if the gene in *H. illucens* were controlled, the gender of the offspring could also be controlled (Aksoy *et al.*, 2014). This could allow us to release a strain of this onto a population, making all offspring males so that they cannot mate, eliminating a population (Aksoy *et al.*, 2014)

CONCLUSION

From this review, three conclusions were reached. They are that *H. illucens*, through its special physiological, ethological and ecological features can be used as a model organism. *H. illucens* larvae can be used in a lab setting because they are easy to take care of as they will eat decomposing matter (Tomberlin *et al.*, 2002). Larvae can also be put into cramped stations in which hundreds of larvae can be stored (Tomberlin *et al.*, 2002). *H. illucens* adults will need more space to live, but will still be easy to take care of as the males no longer need to eat (Tomberlin *et al.*, 2002). The second conclusion of the paper is that *H. illucens* can be used in an industrial setting in order to cut costs and lower multiple types of pollutions on farms. As larvae, *H.*

illucens eats the decomposing matter of the farm animals and after the larvae become pupae, the pupils can be used as food for the farm animals (Tomberlin *et al.*, 2002). This could save farms money as previously, they would have to import their food from other locations, wasting gas and transportation money (Newton, 2005). The final conclusion is that *H. illucens* could be used in order to limit the diseases spread by Tsetse flies (Aksoy *et al.*, 2014). *H. illucens* and Tsetse flies share similar sexual dimorphisms, gender-specific behaviors and a gene that controls the sex of the offspring (Aksoy *et al.*, 2014). These could be used in order to limit and decrease Tsetse fly populations (Aksoy *et al.*, 2014). *H. illucens* and its rise as being used could have larger implications in the fields of ecology, ethology and evolutionary biology (Aksoy *et al.*, 2014). These three conclusions help to expand the use of *H. illucens* into the wider scientific framework. *H. illucens* could be used in ecology to find more genes in specific organisms that can be controlled to help humans (Aksoy *et al.*, 2014). *H. illucens* can also be used in ethology to study the behavior of similar organisms (Aksoy *et al.*, 2014). In evolutionary biology, *H. illucens* could be used by comparing the genes of *H. illucens* to other organisms (Rozkosný, 1983). This could then be used in order to build cladograms and help expand phylogenetic theories (Rozkosný, 1983).

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