Black Soldier Fly Larvae Manual

The Black Soldier Fly Larvae Manual

NRC 396 – Independent Study
Fall 2015

Haeree Park
Sponsor: Dr. Adrian Jordaan

Table of Contents

II. Purpose:

This manual is meant to be a resource for fisheries, hatcheries, and farms of all types that wish to exercise a sustainable management system utilizing black soldier fly larvae through the minimization of waste. Although black soldier fly larvae can be fed to small livestock such as chickens and rodents, this project and manual are tailored specifically to freshwater fish in hopes of closing the significant gap and inefficiencies of fish management and subsequent waste throughout the New England coastal area. There is an evident opportunity to harness black soldier fly larvae's extraordinary bioconversion of organic matter that can lead to not only a higher level of nutritional supplementation, but also the abatement of fees for feed. Researching the various facets of this viable process can lead to several invaluable benefits in the future for any animal management facility.

III. Introduction:

Black soldier flies, *Hermetia illucens* (Linnaeus), is a common fly of the Stratiomyidae family. They are commonly found throughout the Western hemisphere and the Australian region. As adults, the black soldier fly does not possess a stinger, nor do they possess a mouthpart or digestive organs to allow them to consume waste; therefore, they do not bite either. Healthy adults are approximately 7/8 inches long (Hawkinson, 2005) with the female possessing a reddish-colored abdomen while the male's abdomen is more bronze. Their legs are black with pale yellow forelegs. Black soldier fly antennae – which are long, black, and straight – protrude from their head directly forward and do not contain an arista (bristle-like appendage at the tip of the antennae).

Figure 1: Lateral view of an adult *Hermetia illucens*

Black soldier flies mate whilst in flight and females deposit approximately five hundred eggs. The larvae that result are what many researchers and farmers are interested in due to their ability to digest waste. The black soldier fly larvae (BSFL) are impeccable converters of feedstuff/manure into valuable biomass. What this biomass looks like nutritionally is: 40+% protein and 30+% fat, all whilst reducing manure/compost (Newton, 2004). These ½-inch larvae can be immediately fed to fish or through a dried-supplemented diet.

Not only are *Hermetia illucens* disinterested in human residences, and thus reduce the likelihood of disease transmission (Newton, 2005), but they also discourage inhabitation by other common fly species. Their brief life cycles encourage large-scale and long-term production along with the assurance of a reliable source of food due to frequent reproduction.

The larvae of *Hermetia illucens* are viable candidates for mass-production of their natural waste reduction-centered lifestyles. As voracious consumers, BSFL management through a comprehensive and holistic process ensures maximizing efficiency and benefits while minimizing cost.

IV. Breeding:

i. EGGS:

The species of *Hermetia illucens* has a fairly quick life cycle of 5-8 days. A few days after becoming an adult and emerging from a pupal case, female black soldier flies find a mate. How this would occur is a male intercepting a female mid-flight and them both descending in copula. The female does not waste any time to lay 500+ eggs in a dry environment near edges or crevices of decaying organic matter. Each egg is approximately 1 mm in length and creamy white in coloring (W. Diclaro II & Kaufman, 2009).

Figure 2: *Hermetia illucens* eggs on a plastic basin lid

ii. LARVAE:

After these eggs are laid, they remain in this stage for approximately 4.5 days or 105 hours (ESR International, 2008). Once the eggs hatch, the larvae find whatever waste they can and immediately start to consume it. Two weeks later, the larvae have reached full maturity given their environmental conditions are favorable. It may take up to six months for larvae to reach maturity due to black soldier flies' ability to extend their life cycle in hostile circumstances. The larvae can be up to roughly 27 mm in length and 6 mm in width. They have a pale white color with a small black head containing their mouthparts (Newton, 2005).

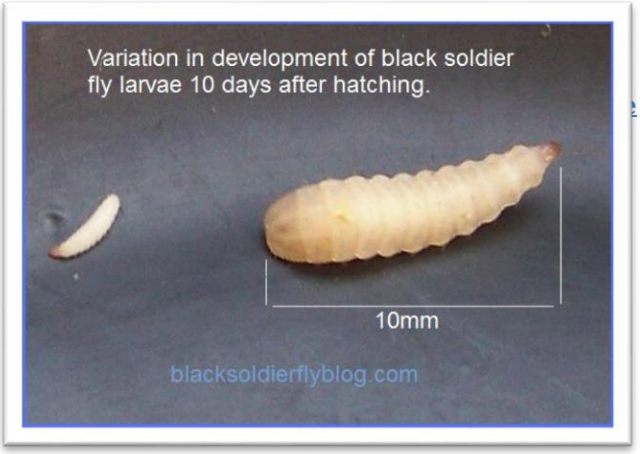

Figure 4.1: *Hermetia illucens* larvae

Figure 5.2: *Hermetia illucens* dried larvae

iii. PUPA:

Following the maturity of the BSFL, pupae stages begin where the sixth instar (final molting phase in *Hermetia illucens*) larvae remove themselves from their feeding sites in search of a dry, sheltered environment. Once this occurs, pupation commences. As a result, the exoskeleton darkens in pigmentation and a pupa develops inside of the exoskeleton. Pupation takes another two weeks before an adult emerges from the pupae case. Then, the adult emerges to reproduce again and the cycle repeats.

Figure 4: *Hermetia illucens* pupa

V. Environmental Conditions:

i. TEMPERATURE:

Black soldier flies are extremely sensitive to their environments; thus, their conditions need to be monitored extensively to ensure the highest yield is obtained. Considering black soldier flies are an equatorial and generally a warm-season temperate species, their lifespan is dictated by how warm their environment is.

An experiment conducted by Jeffrey Tomberlin in 2009 tested the effect varying temperatures had on black soldier flies and their development. What he found was that at a temperature of 27°C (80.6°F) for both males and females, was when larval, prepupal, pupal, and adult longevity was at its most efficient (Tomberlin, 2009). He concluded that smaller adults and a shorter adult lifespan correlate as temperature increases due to higher rates of metabolism and growth. Once temperatures hit a higher threshold of 30-36°C (86-96.8°F), black soldier fly development is acutely inhibited. At a given temperature of 27°C, males and females took ≈2.5d more to complete a pupal stage than at 30°C (86°F). Also, at 27 and 30°C,

83.2-91.8% and 74.2-96.7%, respectively, of individuals survived to become adults. In Tomberlin's conclusion he states,

> "For the black soldier fly, adults reared at 27°C weigh ≈5% more and live roughly 10% longer than those reared at 30°C. However, an average of 4 more d are required to complete larval development at 27°C than at 30°C. Because adults do not feed, other than to take water (Tomberlin et al. 2002), larval feeding is crucial to fitness . . ." (Tomberlin 932, 2009).

From Tomberlin's work with black soldier fly rearing, he has concluded that from the egg stage (≈ 4d) to adults it takes roughly 43d total in his experiment. Utilizing his results and scientific evidence, it is imperative that black soldier flies reared in a New England-based facility with harsh temperatures and fluctuating climates, be well-maintained in this sense to ensure the highest and longest life expectancy rate.

ii. HUMIDITY:

Black soldier flies, as previously stated, are extremely temperature-sensitive. With this, they are also highly receptive to humidity. This variable has considerable ramifications on egg eclosion. Low humidity levels results in water loss through the egg membrane and further desiccation. In a scientific paper published by L.A. Holmes, 25% RH (relative humidity) causes higher rates of desiccation and higher mortality rates on black soldier fly eggs. At 70% RH, adults lived 2-3d longer that adult black soldier flies subjected to lower RH levels (Holmes 976-977, 2012). Therefore, the higher the humidity of the proposed environment, the higher the chances are of a more successful colony. Eclosion at lower RH levels; however, is still possible.

A relative humidity of 30-90% promotes mating and oviposition when eggs and larvae are reared in a 27°C environment. The wide range of relative humidity is indicative of *Hermetia illucens* ability to adapt given the temperature is consistent (Sheppard 697, 2002).

iii. LIGHTING:

Another aspect to be considered is a light source, considering black soldier flies do not mate in the winter months. Naturally, black soldier flies require direct sunlight to encourage mating. Thus, operations indoors require supplemented artificial lighting.

Under natural direct sunlight, 85% of mating activity happened in the morning with 110 μmol m^2s^{-1}. Surpassing 110 μmol m^2s^{-1}, resulted in a decrease in mating activity. A 500-watt, 135 μmol m^2s^{-1} light intensity quartz-iodine lamp

stimulates mating and oviposition at rates and times comparable to those under natural sunlight. Briscoe and Chittka (2001) stated that insects couldn't see wavelengths past 700 nm; therefore, wavelengths between 350-450 nm produced by a rare earth lamp should not be used, as they do not produce mating behaviors. A higher wavelength of 450-700 nm is recommended to produce mating behaviors out of black soldier fly adults (Zhang 3-6, 2010).

iv. DIET:

As adults, *Hermetia illucens* cannot feed; however, automatic or frequent water misting provides an adequate amount of water to the adults. The mists form droplets, which are then taken up by the adults. The adults' main energy source is the remaining fat stored from their larval stages.

Larvae have a much wider range and greater demands for sustenance. *Hermetia illucens* require a certain level of moisture in the organic matter they are consuming.

VI. Feeding Operations:

i. STRUCTURE and DESIGN:

The preferred product to use is a BioPod Plus Auto-Harvesting Grub Composter. The design of the bin consists of:

- 1 body, 1 main lid kit, 1 inner convenience lid, 1 drainage plate, 1 drainage pad, 1 harvest bucket, 1 external drainage assembly
- 26 1/2" long x 15 1/2" wide x 16" tall
  9" diameter of circular top ventilation portal
  Drainage Plate: 27 cm long x 44 cm wide x 0.3 cm thick
- Pair of angled 40" migration ramps that allow black soldier fly larvae to crawl naturally into the Harvest slit
- Inner edge of 2" wide ramps have a raised lip to guide larvae into the harvest slit, which acts as an entry chute to the harvest bucket below
- Covered harvest bucket collects black soldier fly larvae, naturally separating mature and maturing larvae.
  - The bucket has a drip channel that diverts condensation and excess liquid away from the organic matter, and an air slot for ventilation.
- The inner convenience lid pivots easily and shields the top ventilation portal.
- Weather and mold-resistant
-

Figure 6.1: Internal view of BioPod Plus

Figure 5.2: External view of BioPod Plus

In terms of functional capacity, this particular bin can hold a maximum of 2.2 kg/5lbs per day. The bioconversion is projected at 15-20% of food waste into BSFL and a 3-5% bioconversion of scraps into larvae residue. This bin can sustain the equivalent of 3-6 adult chickens.

ii. CALCULATIONS:

In general, the larvae can consume 15 kg/m^2/day of feeding surface area, or 3 lbs/ft^2/day (ESR International, 2008). Roughly, 20% by weight of organic food matter is converted into larvae. This organic food matter consisted of an average 37% dry matter content, and the prepupae had an average 44% dry matter content. Therefore, bioconversion based on ESR International findings comes to 24% (ESR International, 2008).

For reference, a spiral container that is a 2-ft unit has an average feeding surface area of 0.34 m^2. With the rate of 15 kg/m^2/day, the 2-ft unit can contain 5kg of food waste per day, along with 144 liters of larval residue. With a 95% reduction rate of weight and volume, the unit must be emptied after receiving a total of 2.89 m^3 of food waste. A system of this size can sustain a family of four (ESR International, 2008).

VII. The Value of Black Soldier Fly Larvae:

Studies have shown that dried black soldier fly prepupae can be fed to many different kinds of small-animal livestock, amphibians, and fish. It is no secret that the larvae are rich in protein and fat content, but what types and in what quantities? How beneficial are the larvae to the consumer in question?

i. NUTRITIONAL SIGNIFICANCE:

An analysis of dried Black Soldier Fly larvae (ESR International 2008) elucidates that it contains:

- 42.1% crude protein
- 34.8% ether extract (lipids)
- 14.6% ash
- 7.9% moisture
- 7.0% crude fiber
- 5.0% calcium
- 1.5% phosphorus
- 1.4% nitrogen free extract (NFE)

In conjunction with these findings, another research experiment was conducted in the supporting of these statistics. From 1000 black soldier fly eggs; a fixed number were subjected to three varying fish offal and cow manure-mixed diets consisting of homogenized fish heads, viscera, and bony structures from rainbow trout and the subsequent bovine excrement. The results of this approach led to a 43% increase of total lipid in the black soldier flies fed varying proportions of the fish offal compared to the control group of exclusively cow manure. In addition, the levels of omega-3 fatty acids increased (from scant amounts to 3%) in the groups fed the fish offal. The average prepupae composed of 30% lipid: where with fish offal-enriched diet-fed larvae acquired 1% of its total dry weight as purely omega 3-fatty acids (St-Hilaire, Cranfill 2007).

The research had successfully verified that the black soldier fly larvae were able to efficiently bio-convert a considerable percentage of the fish oils and nutritive properties present in the fish offal into invaluable omega-3 fatty acids. Thus, through the supplementation of even a small proportion of fish waste in black soldier fly diets within 24h of pupation (St-Hilaire, Cranfill 2007).

ii. ECONOMIC EVALUATION:

One of the main purposes of black soldier fly larvae use is the promising idea that the nutritional prepupae will be able to cut feed costs down. With the knowledge that black soldier fly larvae, when fed a fish trimming-enriched diet, contain more omega-3 fatty acids and protein than without. Therefore, fish hatcheries should utilize the millions of metric tons -17.9-39.5 million metric tons in

1994 (NOAA Fisheries) through the black soldier fly larvae's efficient ability to produce high-quality fishmeal and supplemented feeds. The National Oceanic and Atmospheric Administration (NOAA) themselves claim to be researching alternatives to feeding fish to fish, as stated: "NOAA scientists are working with industry academic partners to create a production process that can cost-effectively process the trimmings in to a high-value dried meal . . ." (NOAA Fisheries).

Black soldier fly larvae, estimated worth $1.05/lb (Bullock, 2013), can greatly reduce the costs of feed, which amount to 40-50% of total operational costs. Fishmeal, at 65% protein, amounted to $1,647.57/metric ton as of October 2015. This is a 4.08% increase in prices from the previous month, September 2015 (Index Mundi).

Further research is required to validate these assumptions; however, the overall concept remains valid in the scientific evidence shown to support the claims made previously.

VIII. Works Cited:

" ." *Bio Trout*. Bio-Oregon, 17 Sept. 2015. Web. 06 Dec. 2015.

"Bio-Oregon." *BioTrout*. Bio-Oregon, n.d. Web. 06 Dec. 2015.

"BioPod Plus Auto-Harvesting Grub Composter." *Compost Mania*. N.p., 2015. Web. 06 Dec 2015.

"Black Soldier Fly." *Black Soldier Fly*. North Carolina State University, n.d. Web. 06 Dec. 2015.

"BSF (Black Soldier Fly) Forums |People & Places." *BSF (Black Soldier Fly) Forums |People & Places*. N.p., 2015. Web. 06 Dec. 2015.

Bullock, Neill, Emily Chapin, Austin Evans, Blake Elder, Matthew Givens, Nathan Jeffay, Betsy Pierce, Wood Robinson, Susan Caplow, PhD, and John Mattox, PhD. "The Black Soldier Fly How-to-Guide." (2013): 1-12. Web. 6 Dec. 2015.

Diclaro II, Joseph W., and Phillip E. Kaufman. "Black Soldier Fly - Hermetia Illucens." *Black Soldier Fly - Hermetia Illucens*. University of Florida, July 2009. Web. 06 Dec. 2015.

Diener, S., C. Zurbrugg, and K. Tockner. "Conversion of Organic Material by Black Soldier Fly Larvae: Establishing Optimal Feeding Rates." *Waste Management & Research* 27.6 (2009): 603-10. Web. 6 Dec. 2015.

"ESR International." *Bioconversion of Food Waste: Black Soldier Fly*. ESR International, 2008. Web. 06 Dec. 2015.

"Feeds for Aquaculture." *:: Office of Aquaculture*. NOAA Fisheries, 2015. Web. 06 Dec. 2015.

"Free Dried Black Soldier Fly Larvae Sample." *Momma Deals*. N.p., 21 Nov. 2013. Web. 06 Dec. 2015.

Hale, William, Sr. "Black Soldier Fly Blog." *Black Soldier Fly Blog*. N.p., 7 Apr. 2010. Web. 06 Dec. 2015.

Hawkinson, Candice. "Beneficial Insects in the Landscape: #51 Black Soldier Fly (Hermetia Illucens)." *Beneficial Insects in the Landscape: #51 Black Soldier Fly (Hermetia Illucens)*. Galveston County Master Gardeners, 2005. Web. 06 Dec. 2015.

Holmes, L. A., S. L. Vanlaerhoven, and J. K. Tomberlin. "Relative Humidity Effects on the Life History of Hermetia Illucens (Diptera: Stratiomyidae)." *Environ Entomol Environmental Entomology*41.4 (2012): 971-78. Web. 6 Dec. 2015.

Newton, G.L., D.C. Sheppard, D.W. Watson, G.J. Burtle, C.R. Dove, J.K. Tomberlin, and E.E. Thelen. "The Black Soldier Fly, Hermetia Illucens, As a Manure Management/Resource Recovery Tool." (2004): 1-5. Abstract. (n.d.): n. pag. Print.

Sealey, Wendy M., T. Gibson Gaylord, Frederic T. Barrows, Jeffery K. Tomberlin, Mark A. McGuire, Carolyn Ross, and Sophie St-Hilaire. "Sensor Analysis of Rainbow Trout,

Oncorhynchus Mykiss, Fed Enriched Black Soldier Fly Prepupae, Hermetia Illucens." *Journal of the World Aquaculture Society* 42.1 (2011): 34-45. Print.

Sheppard, Craig, Dr. "Phoenix Worms® The Superior Calcium-Rich Feeder." *Superior Nutrional Benefits*. Phoenix Worm, 2015. Web. 06 Dec. 2015.

Sheppard, D. Craig, Jeffery K. Tomberlin, John A. Joyce, Barbara C. Kiser, and Sonya M. Sumner. "Rearing Methods for the Black Soldier Fly (Diptera: Stratiomyidae): Table 1." *Journal of Medical Entomology J Med Entomol* 39.4 (2002): 695-98. Web. 6 Dec. 2015.

St-Hilaire, Sophie, Katie Cranfill, Mark A. Mcguire, Erin E. Mosley, Jeffery K. Tomberlin, Larry Newton, Wendy Sealey, Craig Sheppard, and Stephen Irving. "Fish Offal Recycling by the Black Soldier Fly Produces a Foodstuff High in Omega-3 Fatty Acids." *J World Aquaculture Soc Journal of the World Aquaculture Society* 38.2 (2007): 309-13. Web. 6 Dec. 2015.

Tomberlin, Jeffery K., Peter H. Adler, and Heidi M. Myers. "Development of the Black Soldier Fly (Diptera: Stratiomyidae) in Relation to Temperature: Table 1." *Environ Entomol Environmental Entomology* 38.3 (2009): 930-34. Web. 6 Dec. 2015.

Zhang, Jibin, Ling Huang, Jin He, Jeffery K. Tomberlin, Jianhong Li, Chaoliang Lei, Ming Sun, Ziduo Liu, and Ziniu Yu. "An Artificial Light Source Influences Mating and Oviposition of Black Soldier Flies, Hermetia Illucens." *Journal of Insect Science* 10.202 (2010): 1-7. Web. 6 Dec. 2015.